C-17A SUSTAINMENT PERFORMANCE METRICS ASSESSMENT: REPAIR SOURCE IMPACT ON SUSTAINMENT FOR FUTURE BUSINESS CASE ANALYSIS DEVELOPMENT

Graduate Research Project

Zachary G. Hall, Major, USAF

AFIT-ENS-GRP-13-J-17

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY

AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

AFIT-ENS-GRP-13-J-17

C-17A SUSTAINMENT PERFORMANCE METRICS ASSESSMENT: REPAIR SOURCE IMPACT ON SUSTAINMENT FOR FUTURE BUSINESS CASE ANALYSIS DEVELOPMENT

GRADUATE RESEARCH PROJECT

Presented to the Faculty

Department of Logistics Management

Graduate School of Engineering and Management

Air Force Institute of Technology

Air University

Air Education and Training Command

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Logistics and Supply Chain Management

Zachary G. Hall, MS

Major, USAF

June 2013

DISTRIBUTION STATEMENT A.
APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.

AFIT-ENS-GRP-13-J-17

C-17A SUSTAINMENT PERFORMANCE METRICS ASSESSMENT: REPAIR SOURCE IMPACT ON SUSTAINMENT FOR FUTURE BUSINESS CASE ANALYSIS DEVELOPMENT

Zachary G. Hall, MS

Major, USAF

Approved:

Darryl K. Ahner, PhD, PE	Date
Sharon G. Heilmann, Lt Col, USAF	Date

AFIT-ENS-GRP-13-J-17

Abstract

The C-17A Globemaster III began service on June 14, 1993 and demonstrates some of the highest levels of aircraft availability in the USAF inventory. The sustainment activities responsible for these levels are conducted through a public-private partnership. The Air Force entered this sustainment partnership without the advantage a business case analysis (BCA). In June, 2006, the Department of Defense Inspector General (DoDIG) directed the creation of a BCA for the C-17A program to assess all alternative sustainment strategies, along with recommendations for best-value alternatives. Starting in 2007 and completed in 2009, the BCA provided analysis of three areas for predicting sustainment objective accomplishment: benefits, cost, and risk. While the 2009 BCA encompassed the most detailed assessment of alternatives to-date, it contained shortfalls. Analysis of the benefit metrics showed significant interaction between the chosen metrics resulting in skewed analysis and difficulty discerning between options. The objective of this study was to develop mutually exclusive BCA benefit metrics to assess sustainment strategies, weights to use within a decision analysis framework to better inform future BCAs, and develop business rules to exclude data during transitional phases of sustainment in supporting datasets.

To my loving wife, my four children, and the men and women who maintain and sustain this and other magnificent aircraft keeping countless lives safe in the conduct of our nation's global missions. Thank you.

Acknowledgments

I would like to express my sincere appreciation to my faculty advisor, Dr. Darryl K. Ahner for his guidance, encouragement, and support throughout the course of this graduate research project effort. His insight and direction proved invaluable leading to experiences and learning both within the scope of the project and far beyond. I would like to thank Lt Col Sharon G. Heilmann for her help with this project, her mentorship throughout this past year, and for her example of officership. I would like to thank Mr. Mark Fryman for his guidance, insights, and tireless efforts to secure resources. I would also like to thank my sponsors from the Air Force Materiel Command's Air Force Life Cycle Management Center, and Mr. Austin Klaus for both the support and latitude provided to me in this endeavor.

Zachary G. Hall

Table of Contents

Page

Page

Page

List of Figures

Page

List of Tables

Page

C-17A SUSTAINMENT PERFORMANCE METRICS ASSESSMENT: REPAIR SOURCE IMPACT ON SUSTAINMENT FOR FUTURE BUSINESS CASE ANALYSIS DEVELOPMENT

I. Introduction

Background

In June, 2006 the Department of Defense Inspector General (DoDIG) directed a business case analysis (BCA) be conducted on sustainment strategies for the C-17A. Specifically, the DoDIG stated the BCA should be an objective analysis thoroughly evaluating multiple sustainment options for the C-17 aircraft to ensure the government makes a knowledgeable, best-value decision for long-term sustainment (DoDIG, 2006). At the time of publication in 2009, the C-17A was both in a production and a sustainment phase and was operated by eleven domestic and three foreign military bases with slightly more than 206,000 total flying hours (AFTOC, 2013). The 2009 C-17A BCA (hereafter referred to as the 2009 BCA) represented a collection of data and analysis to offer the USAF and DoD senior leaders several courses of action for the sustainment options of the C-17A with respect to metrics assessing benefits, cost, and risk of different sustainment options. The BCA was the culminating efforts from over 20 people spanning 2 years and sought to produce recommendations on the 30-year sustainment program.

The C-17A Globemaster III began service on June 14, 1993. Nearly 20 years into its service life, the C-17A demonstrates some of the highest levels of aircraft availability of any aircraft in the USAF inventory. Part of the concern from the DoDIG was directed at the value aspects of this aircraft availability. Since the most recent standard set for aircraft availability in 2009, the standard has been routinely exceeded but not without accompanying costs. In order to fully inform the discussion on sustainment strategies, we must also be able to quantify, in terms of cost, what exceeding the aircraft availability standard means. Next, we must determine whether this is an appropriate trade off to make. A BCA is an important step in this assessment and one to be carefully considered and created. The 2009 C-17A BCA recommendations positively affirmed a government-led collaboration between the USAF and The Boeing Company (hereafter referred to as Boeing) as the best-value solution for C-17 sustainment (Business Case, 2009). Furthermore, the recommendations also positively contributed to the USAF's goal of maximized aircraft availability through incentives given for performance and the reduction of unavailability based on maintenance, supply, and depot issues.

Overall, the 2009 BCA assessed seven potential cases for consideration. The cases were constructed according to integrator type and support provider. Furthermore, evaluations considered the cases' ability to attain certain specific and measureable attributes relating to depot performance. These attributes were compiled, then prioritized by subject matter experts examining workload assignments relative to pre-defined criterion. Following the analysis, the BCA set forth three potential courses of action, recommending one case as the best value of benefits, cost, and risk. From the recommendation of the BCA, the USAF, acting on behalf of the other governments in partnership with the C-17A fleet, made several changes to the recommendation. Boeing was then presented with the changed recommendation. Boeing offered to meet the cost savings requirements without transitioning to the recommended course of action inclusive of the changes proposed from the USAF. The Boeing offer represented the status quo with continued efforts to reduce costs and realize performance improvements. The current state of affairs notes little change to the 2009 environment with the exception of the Government acting as the primary source manager and the ongoing effort to transition the engines.

The 2009 BCA analyzed seven different sustainment cases. Case 1 represented the present conditions at the time of the study and the baseline case in which Boeing retained obligations as the Total System Support Responsibility (TSSR). Case 2 represented a theoretical boundary condition in which Boeing retains TSSR, and, in addition, all Government sustainment functions would transition to contractor support (Business Case, 2009). Case 3 represented another theoretical boundary condition of 100% organic sustainment. This case obligated Warner Robins Air Logistics Center (WR-ALC) support through a system support manager, namely, all contractor sustainment functions transition to the Government. This construct would have been required to undergo a formal contract bidding and award process in order for the WR-ALC to assume this responsibility. Case 4 represented a Boeing TSSR/organic mix unconstrained by Core and 50/50 requirements (Business Case, 2009). This case called for a contractor-led best value collaboration of contractor and government sustainment activities not constrained by Core or 50/50 requirements by either requesting a waiver or relying on separate weapons systems to balance Core and 50/50 requirements (Business Case, 2009). Case 5 represented a Government Product Support Manager (PSM)/Contractor Mix and also unconstrained by Core and 50/50. This case represented a government-led best value mix of contractor and government sustainment activities (Business Case, 2009). Case 6 represented a Boeing TSSR/Organic Mix, constrained by Core and 50/50 requirements with a contractor-led best value mix of contractor and

Government sustainment activities. Case 7 represented a Government PSM/Contractor Mix, constrained by Core and 50/50 requirements with a government-led best value mix of contractor and government sustainment activities.

The 2009 BCA recommended Case 7 as the best course of action to the USAF. However, the USAF augmented this case with program management and engineering responsibility given to the Government. The USAF briefed the augmented BCA case to Boeing as the desired course of action based on attained levels of aircraft availability (among many other attributes) and depot performance. In lieu of making this transition, Boeing agreed to meet savings projections while operating under the current state (Case 1) with several changes. Those changes were: increased program management workload, product support, materiel and depot management; and avionics and software responsibility performed primarily by the contractor (90%). Based on a recommendation from the 2009 BCA, the USAF also started a program for transitioning the engines to a direct support contract (with potential of savings at $1.6B).

BCA Shortfalls

The 2009 BCA was the first of its kind for the C-17A Globemaster III. As such, the BCA helped pioneer certain aspects of valuable analysis an provided key insights to this project but not without shortfalls. The 2009 BCA had several shortfalls in the analysis and the recommendations. The use of weighted dollar values, overlapping and inclusive benefit metrics, analogous weapons system data derived from sustainment strategies not in use, incomplete analysis of the savings estimate through engine competition, no analysis of alternate cost savings methods, and recommendations exceeding the scope of analysis all contributed to a product of limited use. Weighing dollar values carries the implication certain dollars are more important than other dollars. Overlapping benefit metrics lead to double- and triple-counting with interactions between variables measuring the same trait. Weapons system data was either derived or extrapolated for certain benefit metrics in the 2009 BCA. Sustainment strategies not in use are not defendable through data or historical evidence were used to make recommendations used in the 2009 BCA. Data for the component product deficiency rates were collected from only three national stock numbers. The 2009 BCA recommendation to compete the sustainment contract for the C-17A engines is not a best-value recommendation since it did not include analysis of benefits, cost, and risk. The 2009 BCA also did not assess changes in incentive structures. Consequently, a complete analysis was not performed.

One of the BCA shortfalls was the discrepancy between the analysis and the scope of the recommendations set forth. The aim of the 2009 BCA was to thoroughly assess sustainment options for the C-17A and ensure the Government makes a knowledgeable, best-value decision for long-term sustainment (Business Case, 2009). The 2009 BCA used analysis of benefits, their respective costs projected out to a term of thirty years, and their associated risks over that period as described in the various models used (Business Case, 2009). However, not all recommendations followed this informed process. One recommendation was not a best-value recommendation in terms of the associated risk, cost, benefit, and incentive analysis but followed with the estimate of significant cost savings to the C-17A program.

The BCA attempted to create unique sustainment cases to attain the best-value mix or performance, cost, and risk for the 30-year cost profile. The 2009 BCA cost profile did not include analysis of cost changes over the lifecycle due to the reliability curve (bathtub effect), aging aircraft, changes in fleet size, and changes to the operational environment. No sensitivity analysis was not performed around these potential impacts to generate a range of suspected values given a future state. Lastly, the unique sustainment cases did not correspond to sustainment programs used by other aircraft. These derived data profiles did not have fully listed assumptions.

The 2009 BCA did not propose different contractual incentive structures the Government may use as options to incentivize Boeing for sustainment activities in addition to the proposed sustainment cases. In other words, the 2009 BCA aimed to show the only method of improving sustainment or achieving certain sustainment goals was to integrate government and contractor activities without looking at a different potential alternative altogether – a set of different incentive structures for the contractor in contrast to the current incentive options. Incentive analysis seeks to make changes within contracts to make them cheaper by considering reductions in performance thresholds, changes to incentives offered, or changes to the entire payment contract used.

Additionally, the 2009 BCA used weighted dollar values to assess projected values of sustainment cases. Weighted dollar values can be misleading by placing higher priorities on certain dollars over others. Dollar-to-dollar comparisons are one tool for comparison; weighing dollar values complicates comparisons. Lastly, the 2009 BCA stated the largest cost savings could be realized through the competition of the sustainment contract for the C-17A engines (Business Case, 2009).

The BCA demonstrated shortfalls insofar as the interactions between metrics chosen. A major point in decision analysis is to use decision variables that do not measure the same attribute. This key aspect of the 2009 BCA represents the primary focus of this project. Aircraft availability represented the highest weighted metric. However, the sub-factors of aircraft availability were also metrics used in the analysis of depot sustainment. The presence of both aircraft availability and its sub-factors obscure clearly differentiated options since components of one factor are included again in others. Choosing one option over another is complicated when one of the options includes factors of the second option – the two options are not distinctly different from each other because the first directly influences the second and vice versa. This project sought to propose metrics without such interactions and to propose a framework for their use to assess and to predict the impact of changes in the sources of sustainment. This project uses sustainment structures currently used in similar-type aircraft to assess their efficacy and performance with regard to aircraft availability.

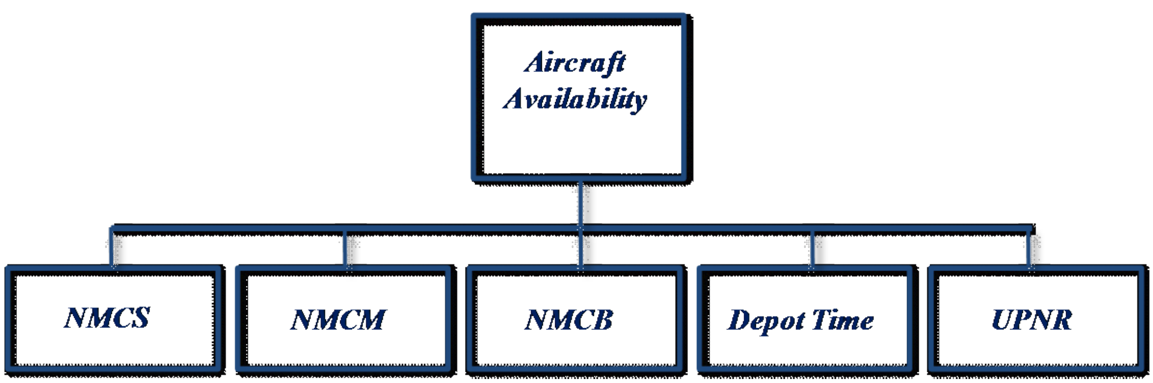

Figure 1: Aircraft Availability Sub-Factors

Instead of using primary-factor *and* sub-factor metrics, this study uses only sub-factor metrics to prevent such interactions between the chosen metrics. Mutually exclusive metrics allow decision assessment based on their accomplishment of desired objectives.

The original scope of this project was to update the 2009 BCA with current performance data relevant to the changes in the operating environment, fleet size, associated sustainment risks, and their respective costs. The first step in the original scope was to evaluate the assumptions of the model and determine whether they were still valid. However, under a review process intended to produce an updated version of the 2009 BCA to meet with the five-year requirement for program review, analysis of the benefit metrics showed the aforementioned sub-factor interference. The benefit metrics did not all represent clear alternatives making the choice between the proposed sustainment strategies unclear. The intent of decision-making is to produce a desired consequence. However, when there is little difference between the alternatives, one cannot be sure the decision made will have the desired consequences.

The 2009 BCA Benefit Metrics formed the foundation of analysis from which costs and risks were then derived. Four of the seven Benefit Metrics assigned to identify differences in performance measures corresponding to sources of repair measured sub-factors of the primary metric – aircraft availability. Consequently, when data for one benefit metric was collected and input into the benefit model, it already included the data for other metrics subsequently input into the model.

Prioritized Benefit Attributes	Weighted Value
Normalized Aircraft Availability Rates	24.0%
On-Time Delivery Rate	20.2%
Routine Depot Assistance Request Response Time	13.5%
Indexed Non-Mission Capable Supply Rate	12.9%
Component Product Quality Deficiency Report Rate	8.2%
Customer Wait Duration	7.9%
Issue Effectiveness Rate	7.2%
Stock Effectiveness Rate	6.0%

Sub-factors of Aircraft Availability

Figure 2: 2009 BCA Benefit Metrics Sub-Factors of Aircraft Availability

As a result, metrics were double-counted. If sustainment decisions were designed to improve stockage effectiveness rates, for example, that decision would not be different from a decision to improve non-mission capable rates for supply, customer wait times, or aircraft availability. The consequences for the decision are not different because the decision metrics were not mutually exclusive.

The measurement of sub-factors in addition to the primary metric introduced analysis problems by giving the sub-factors more importance, double-measuring, and failing to distinguish between viable alternatives. Consequently, the BCA recommendations did not provide accurate measure of each of the seven cases and an update to the 2009 BCA would have resulted in further skewed analysis and the inability to delineate between alternatives. Since the release of the 2009 BCA, there has been interest in re-assessing the model and assumptions to more realistically incorporate mutually exclusive variables without sub-factor interaction.

Additional shortfalls of the BCA related to areas outside the scope of this project are included to better inform future BCAs. In the 2009 BCA, there were unclear descriptions on the methodology of weighed dollar values used in the cost analysis of the models and a lack of projected ranges for each of the seven cases. The metrics chosen in the benefits section were the amalgamation of many surveyed responses from both the field and program experts. Ultimately, these metrics failed to reflect the items of influence on the balanced score card (BSC) used by Air Force Materiel Command (AFMC). The "On-time Delivery Rate (original and revised)" metrics were determined to have an additional weighting of 53% and 47%. It is unclear how this method best informs the weighted utility score of those values. Analysis performed for this research project could not conclude the model's purpose for this step.

Problem Statement

This graduate research project (GRP) seeks to develop a defensible benefit analysis methodology for the C-17A BCA. The methodology establishes mutually exclusive benefit metrics to assess depot performance within existing sources of repair; proposes a structure for weights and comparisons within a decision analysis framework to better inform future analysis; and establishes business rules for data that excludes data during sustainment transitional periods. Since analogous weapons systems and their corresponding sustainment strategies established the framework for comparisons in this study, organizational structures to increase aircraft availability may also be inferred to provide inputs for future BCAs and develop a framework for decision analysis for use across other weapons systems.

Research Objectives

The purpose of this project is two-fold: to develop mutually exclusive BCA benefit metrics to assess sustainment strategies and to develop a model to use within a decision analysis framework to inform future BCAs.

Research Questions

Research Question 1: Are the 2009 BCA prioritized benefits metrics mutually exclusive?

Research Question 2: How were the weights determined?

Research Question 3: Is there evidence this is the correct weighing of these benefit metrics?

Research Question 4: What metrics can best capture the impact on aircraft availability given changes in the source of repair?

Research Question 5: What sources of data exist for the assessment of sustainment performance strategies?

Assumptions

Assumption 1: The main factors affecting aircraft sustainment are addressed through policies directly relating to non-mission capable for supply (NMCS) rate, non-mission capable for maintenance (NMCM) rate, non-mission capable for both supply and maintenance (NMCB) rate, and Depot Time rate.

Assumption 2: The data collected on chosen metrics is accurate and complete, reflecting actual rates of the chosen aircraft availability sub-factors.

Assumption 3: The metrics chosen reflect the most important factors of aircraft availability, and furthermore, these metrics impact sustainment decisions.

Assumption 4: There are inherent differences between NMCS, NMCM, NMCB, and Depot Time rates based on the source of repair.

Assumption 5: The average values of NMCS, NMCM, NMCB, and Depot Time rates will yield the best and most logical value for those metric over the specified duration of time.

Assumption 6: Measuring sub-factors of NMCS, NMCM, NMCB, and Depot Time rates result in the best assessment of the source of repair's impact of these sub-factors.

Assumption 7: Past performance is capable of predicting average values of NMCS, NMCM, and NMCB to project future values given a constant source of repair.

Assumption 8: Data for first three years of aircraft sustainment after a change in repair source is not representative of the eventual sustainment level achieved along the reliability growth curve once the aircraft reaches maturity.

Assumption 9: Data for first five years of aircraft sustainment after initial production is not representative of the eventual sustainment level achieved once the aircraft reaches maturity along the reliability growth curve.

Business Rules

Business rules created for this project allowed for consistent and appropriate data use representative of sustainment strategies consistently and appropriately. The business rules were guides to aid in the comparison of NMCS, NMCM, NMCB, and Depot Time rates across the various sustainment strategies evaluated. Business rules addressed which models of aircraft could be included in the analysis, which years of data were appropriate representations of sustainment strategies, and which sustainment strategies would be assessed.

Sustainment programs currently in use were the basis of comparison for this project. The study used data from aircraft availability to represent sustainment programs currently in use. This project does not seek to fully capture every aspect of aircraft availability but instead measure the causal relationships of activities within the sustainment programs studied as a method of proposing a similar sustainment strategy for the C-17A. Concurrently, the project is limited to the C-17A since the weighted values used in the model were informed by the 2009 BCA.

Aircraft availability includes non-mission capable statuses for maintenance (NMCM), supply (NMCS), both maintenance and supply (NMCB), and unit possessed not reported (UPNR). Data for unit possessed not reported (UPNR) was not included in the measures of depot effectiveness. Data for UPRN were excluded because the metric was a measurement of only unit-level impact of downtime and did not represent a metric with impact beginning on the depot level. Additionally, UPNR represents a short-term status for an aircraft awaiting disposition – that is, the aircraft is not mission capable but the exact nature, classification code, or reason the aircraft is broken has not been officially designated. Aircraft in a UPNR status do not stay in this status for long periods of time and eventually get assigned a more appropriate status of NMCM or NMCS. Insofar as their impact to aircraft availability, UPNR metrics represent aircraft with downtime that is not charged to the unit with maintenance responsibility. UPNR is not directly tied to depot-level maintenance impact. To prevent sub-factor interactions, PDQR and UPNR were removed from the benefit metrics assessed.

Analyses of only the main sub-factors of aircraft availability are certain to leave some margins unexplored. There are many areas and separate metrics that impact NMCS, NMCM, NMCB, and Depot Time. Customer wait time, issue effectiveness rate, and stockage effectiveness rate are all measures impacting NMCS. This research aims to differentiate NMCS, NMCM, NMCB, and Depot Time rates by source of repair to further inform analysis of tertiary or subordinate metrics as areas to concentrate efforts.

Specifically noting the over-arching metric, such as NMCS, is certain to under-value policies and strategies that target the more-immediate and measurable factors that contribute to NMCS. In other words, all activities associated with reducing NMCS, NMCM, NMCB, and Depot Time are not ubiquitous across all sustainment programs. Furthermore, some aircraft are more complex than others and consequently result in differing aircraft availability sub-factor rates, regardless of sustainment strategy. By choosing to restrict the benefit metrics of this project to the lagging factors, we are limited to measuring their importance and not all of the smaller components that go into the larger metrics.

There was insufficient time and study devoted to the precise and relevant weights of NMCS, NMCM, NMCB, and Depot Time rates used in this model. As these metrics posed the most logical metrics and given their mutually exclusive nature, they may not represent the only method of assessing sustainment program performance benefits. Further analysis and study should be devoted to both the efficacy of their use and the respective weights assessed to each metric. Of the potential benefit metrics proposed for inclusion in this project, those metrics: product quality deficiency report rates, mean time between repairs, and maintenance man-hours were not chosen. They were excluded from the benefit model in this project because their inclusion either did not provide sufficient trade space or their impact was already captured in the chosen metrics.

An additional business rule related to which aircraft sustainment program data were entirely excluded from the analysis. Aircraft models completely phased out with sustainment systems no longer in place were not used. The E-8A was not used since its last recorded presence in the primary database used for this project was 1995 (LIMS-EV, 2013). The C-5C was not used since there are only two of these aircraft in the USAF inventory and any analysis of their sustainment strategy using the metrics proposed in this study would have dramatically skewed the data (LIMS-EV, 2013). The C-130A and B models were not used because they were phased out in 1994 and 1995, respectively (LIMS-EV, 2013). Sustainment program data for the KC-135A, B, and E models were also not used. The KC-135A and B models have been converted to R and T models over the years (KC-135, 2011). The KC-135E was retired in 2009 and data on the sustainment of this aircraft was not collected (KC-135, 2011).

Other data excluded from this analysis pertained to more recent procurements in the USAF inventory. Data on the C-5M and C-130J sustainment programs were collected. The C-5M showed NMCM rates fluctuating between 18% and 25%, evidence of an immature reliability growth curve in addition to only having 9 aircraft in the inventory. The C-130J sustainment program appeared to represent not only a competitive sustainment strategy but would have resulted in a lower overall benefit model score than the current C-17 sustainment strategy. The reason the program was excluded was because of the recent opening of the dedicated C-130J Depot at Robins Air Force Base, Georgia. Based on the first time use of a new maintenance and sustainment strategy similar to ones commonly used in airlines, the program is still in the transitory period. There is still learning that has not yet been reflected in sustainment performance factors.

The exclusion of data for the C-5M and C-130J sustainment strategies represents another limitation of this project. The recent nature of operations at the C-130J Depot led to the exclusion of that data all-together. Based on the design of sustainment operations at the C130J Depot and the unique apportionment of only those activities that are best suited for execution at the depot may likely result in low, long-term Depot Time rates. Of note, the program data for the C-130J was available for analysis in LIMS-EV. Depot Time rates were recorded for the period of time since its initial production. However, the absence of a dedicated depot resulted in the likelihood those rates were not comparable to other aircraft's depot time rates. Consequently, all data for the C-130J program was excluded. Additionally, the C-5M was found to be in the immature stage of its expected reliability growth curve by this project. There is evidence to demonstrate the current C-5M and C-130J sustainment strategies are effective. However, the newness of the airframe resulted in exclusion to account for learning, training for maintainers, and development and maturation of logistics and supply chain functions. All these factors have shown to improve performance with maturity but a fair assessment of either aircraft's sustainment strategy cannot be made at this time with regard to NMCS, NMCM, NMCB, and Depot Time rates.

Data considered was analyzed for anomalies that may skew analysis and vetted for the impact of program transitions, maturity of the reliability curve, and number of aircraft in the fleet. Data previous to FY1994 was considered either too dated or unrepresentative of the current practices in the view of the authors of this project.

Larger fleet sizes create economies of scale and lower values in aircraft availability sub-factors per individual aircraft. It was noted in the data for aircraft types with smaller fleets the increase in NMCS, NMCM, NMCB, and Depot Time rates were impacted more significantly than aircraft types with larger fleets. There was no manipulation or adjustment to the data to account for or correct this. Small fleet sizes dramatically impact the value of the sustainment performance metrics chosen for this project. The converse may also be true whereby large fleet sizes could act to mask certain inefficiencies or spikes in sustainment performance metrics.

Lastly, the findings from this project are only relevant to the chosen benefit metrics. There was no cost or risk analysis performed on any of these options and therefore, the best-value sustainment option cannot be determined from this project. At the conclusion of cost and risk assessments, the data may reveal the PSM/PSI sustainment strategy does not represent the best-value option because other sustainment strategies perform better in the cost or risk areas. Further analysis may also reveal the best-value sustainment strategy can be achieved through changing how incentives are offered to the contractor and not embodied in a government-contractor activities mix. The degree and structure of these incentives were not analyzed in this project and are mentioned only to strongly urge their inclusion in the future BCA. The full scope of activities mix and incentives would meet the intent to assess all relevant sustainment options and not limit analysis to a mix of government and contractor activities.

II. Literature Review

Overview

The focus of the literature review will be on the need for a fully informed BCA, the current sustainment strategy for the C-17, the methods of ascertaining pertinent and measurable metrics to assess, a framework for their analysis, and lastly, the efficacy behind this logical approach. Additional literature review will provide critique and criticism to the methods used in this project.

The C-17A Globemaster III began production in June, 1991 and the first aircraft was delivered in September, 1993 (Air Force Factsheet, 2012). The C-17A has undergone two distinct sustainment program transitions. During its first years of production and delivery from 1991 until 1998 it was produced and sustained by Boeing (C-17 GISP, 2012). After 1998, Boeing transitioned to a system-level, performance-based program using the facilities at the Warner Robins – Air Logistics Center (WR-ALC) in Georgia (C-17 GISP, 2012). From 2009 to the present, Boeing has acted as the sole-source lifecycle support provider (product support integrator or PSI) with the USAF acting as the PSM charged with program management among other responsibilities.

The aircraft routinely operates over 200,000 flying hours per year and conducts missions on all seven continents in fulfillment of the United States' global obligations (AFTOC, 2013). Missions vary from theater-direct delivery to strategic airlift, aeromedical evacuation to night airdrop missions. It is clear the C-17 helps our nation attain its national security objectives. Sustaining this aircraft to ensure its availability and viability for the coming decades is of the upmost importance, perhaps even more so in fiscally challenging environments. A well-informed and carefully constructed BCA will undoubtedly help toward those aims.

The Need for a BCA

A report on public-private partnerships at USAF maintenance depots revealed a lack of business case analysis-based support on the efficacy of such partnerships. The C-17A sustainment program was one of many sustainment programs underway without the advantage of being informed by a BCA. Specifically, the DoDIG report on July 26, 2006 determined the following:

> Air Force officials did not use an appropriate methodology for making the acquisition decision to procure contractor total system support for the C-17 aircraft. Specifically, the Air Force decision to award total system support responsibility was not based on a BCA. This occurred because senior Air Force officials directed the C-17 program office to focus efforts solely on a partnership with the contractor without fully considering additional sustainment strategies. As a result, the Air Force awarded an $871 million long-term contract (with a potential value of almost $5 billion) without proper and necessary support and did not make fully informed sustainment strategy decisions. These decisions will impact future options for sustaining the C-17 when aircraft production is complete. Furthermore, unless the Air Force develops and completes a thorough BCA, it will increase the risk of implementing for the life of the aircraft a sustainment strategy that does not achieve best value.
>
> DoDIG, 2006

A well-informed BCA with mutually exclusive decision criteria assessing both contractor-government activities mix and incentive programs would allow sufficient analysis of all alternatives to ensure the USAF received the best value.

AFI 65-509 details the composition and components of a BCA. The accepted definition of a BCA is:

> A business case analysis (BCA), also referred to as a business case or business plan, is a decision support document that identifies alternatives and presents business, economic, risk, and technical arguments for selecting an alternative to achieve organizational or functional missions or goals. BCAs do not replace the judgment of the decision maker, but rather aid that judgment by considering possible alternatives, their costs, benefits, and risks, and the degree to which they meet program objectives, or are either within budget constraints or require additional funding. A BCA can vary in size and scope depending on the requirements of the decision maker or reviewing organization. The purpose of this instruction is to illustrate what a BCA is by comparing it to other analytical products, explain when BCAs are required in the Air Force, advise on when they may be completed even if not strictly required, state the responsibilities

> of offices involved in completing a BCA, and refer individuals to additional, detailed guidance on how to accomplish BCAs (AFI 65-509, 2008).

As stated above, the BCA should consider the appropriate balance and mix of Government and contractor sustainment activities but also include financial evaluations of incentive structures in order to comply with DoDI 4151.21 (2007) guidance to consider the best business practices.

The Current Sustainment Strategy

Currently, Boeing executes PSI requirements using the facilities, expertise, and personnel at the Warner-Robins Air Logistics Center (WR-ALC). The Air Force Life Cycle Management Center (AFLCMC) provides program management and engineering support to the C-17A as the PSM. The ultimate effect of this unique partnership results in some of the lowest NMCS, NMCM, NMCB, and Depot Time rates for any similar aircraft in the USAF fleet (LIMS-EV, 2013). Graphical depictions of these rates compared to the rates of other aircraft are found in Appendix A.

There have been numerous studies assessing the performance of depot maintenance and sustainment programs. Kem (1999) PhD described the principle performance metrics of depots should focus on out-put, cost, and quality. Furthermore, he advocated workload, efficiency, effectiveness, and productivity measures that, according to Ammons (1996), measure planning and budgeting, operational improvements, resource allocation, and monitoring tasks. There are a myriad of sources rooted in Air Force Instructions (AFI) and manuals directly describing how certain activities will be conducted at depot maintenance facilities. In addition to the standard definitions and depot level requirements and the calculation methods described in AFI 21-103, Equipment Inventory, Status and Utilization Reporting, the Air Force Logistics Management Agency's Maintenance Metrics handbook contains much of the reasoning behind the principles used as well as a short history of the evolution toward more accurate metrics. Furthermore, the Maintenance Metrics handbook describes leading and lagging indicators of aircraft availability sub-factors and directs action toward specific responses in order to affect positive responses. There is a cause and effect relationship between leading and lagging indicators. As the Maintenance Metrics handbook states, leading indicators directly reflect maintenance's capability to provide resources for mission execution and lagging indicators show trends in those capabilities (Maintenance Metrics, 2009).

Metrics

When data was unavailable for the C-17A, data from analogous weapons systems were used. Table 4-5 in the 2009 C-17 BCA, *Appendix 4: Cost Benefit Analysis,* (Business Case) shows which analogous weapons systems were used for each particular benefit metric where appropriate. This study found disruptions to sustainment performance factors caused by certain events. Not all metric data collected represented the sustainment strategy. When programs underwent transitions, plateaus appeared in aircraft availability sub-factors. There is no evidence to suggest data was excluded from analogous weapons systems in the 2009 BCA. to demonstrate the presence of

Troughs in aircraft availability were observed when the source of a sustainment program was changed or transitioned from the government to a contractor. The range of

KC-135R data used for the 2009 BCA was not described in the study. There is reason to believe the metrics from the 2009 BCA exhibited similar traits during program transitions. In addition, the partition of the KC-135R sustainment program between organic and contractor was not fully described and it is unknown what selection criteria were used to enter aircraft into the organic depot or the contractor depot. Over the service life of the KC-135R, there have been changes to its sustainment program and, according to a finding of this study, there should be associated exclusionary periods during which time this data is not used. Lastly, the benefit metric relying on data from analogous weapons systems (component product quality deficiency report rate) was based on only three national stock numbers for the C-17A and only eight from other weapons systems. Nonetheless, this metric received 8.2% of the model's weighted priority – roughly one third of the priority of the aircraft availability rate.

The 2009 BCA Current State lists the assumptions surrounding the operating environment present at the time of the study. However, there is no sensitivity analysis present in what impact additional C-17A's would have on the metrics chosen. Furthermore, the largest area of potential cost savings came from assuming a cost savings of $1.6B could be realized by competing the sustainment policy of the engine. Throughout the report, there is no evidence offered to support this statement of savings by openly competing the C-17A's Pratt & Whitney F117-PW-100 turbofan engines. The cost of programs to research and prepare for this transition as well as the potential risks and benefits for such a course of action were not mentioned in the 2009 BCA.

Depot assistance request response rate data were divided into two different categories for reporting and recording; routine, and emergency data. The emergency data for this metric was unused because it was not collected or reported in a standardized manner allowing for equitable comparisons across weapons systems. There was no evidence suggesting routine data was representative of this measured rate void of the entire body of both emergency and routine requests.

Such an undertaking as this BCA was, it represented a valuable step toward understanding sustainment decisions. Moving forward for the work of countless professionals and their valued inputs, constructing the next BCA should include lessons learned from the 2009 BCA to improve its quality and efficacy.

The current C-17A standards for NMCM, NMCS, NMCB, and Depot Time rates are found in Figure 9, Appendix A. As the program continues to mature, these rates will likely change representing new practices, strategies or policies and continued learning. The current standards were established in 2009 (LIMS-EV, 2013) but have changed many times before then. There is reason to believe, according to Wilhelm, Behrens and Cameron (2011), constant standards of NMCM, NMCS, NMCB, and Depot Time do not offer the best solution to evaluate the capabilities of depots. As valuable as these standards are to identifying performance, they do not capture the full scope of the dynamic activities present in sustainment strategies. These performance metrics do not quantify the impacts of proper supply chain management activities, logistics functions, and many other critical aspects of sustainment. While these proposed metrics ultimately represent the acquisition framework, events, and milestones, their effect is recognized within the aggregate of their impact to aircraft availability. Certainly, the trade-space with the non-mission capable sub-factor rates and Depot Time rates represent the area for sustainment focus, strategy development, and execution. Fixating on certain standards, according to the Maintenance Metrics handbook, could result in lost opportunities to make proportionately more progress towards positively affecting one metric, even to the slight detriment of another metric (Maintenance Metrics, 2009). The sub-factors of aircraft availability used for this project were chosen based on their mutually exclusive nature, among other traits, and the fact they can be impacted by numerous activities. The standard applied to aircraft availability in the 2009 BCA did not account for the natural process of learning over time. Furthermore, program transitions causing sustainment performance disruptions would have been included in this metric as well and could have skewed the analysis.

BCAs focusing on depot maintenance and aircraft sustainment have historically measured distinct attributes and metrics. Most applicably, a recognized “best practice”, as advocated by Kaplan (1993), used a balanced scorecard to assess cross-functional areas within an organization to assure local optima are not working to the detriment of other functional areas. Brown later expanded this work through a strategic model to measure the balanced scorecard as cited in Graham (1996). Both Kaplan and Brown viewed performance metrics as the key success factors achieving goals and objectives in-line with strategies. Recounting Ammons (1996) study of the performance measures of workload, efficiency, effectiveness, and productivity, arguably all of these measures are contained within the factors driving NMCS, NMCM, NMCB, and Depot Time rates. Though this project does not result in a completed BCA, the metrics chosen exhibit the ability for further study within the context of research performed by Ammons (1996) and Kaplan (1993).

In terms of out-put, cost, and quality, the benefit metrics chosen for this project all reflect indicators of activity levels impacting quality metrics tied to costs (Ammons, 1996). Additionally, they serve as "normalization factors" to facilitate comparison between activities not directly comparable. In simpler terms, a particular sustainment strategy's attainment of low NMCM rates draws comparison to a different sustainment strategy to determine areas for improvement through replication or adaptation of successful activities. Each activity required for sustainment and evaluated on its merit to positively impact aircraft availability also has an associated cost. Understanding costs as either operating costs or capital costs makes possible the assignment of expenses to activities or overhead and help analyze the amount of productivity an activity has. Such an understanding is possible using the aforementioned benefit metrics. Lastly, quality measured with quantitative metrics gives the benefit of assessing what Ammons (1996) states as difficult to ascertain – the timeliness and thoroughness of repairs.

Overview of Aircraft Availability

The target aircraft availability rate of 72.9% also represents a standard for which the individual goals of NMCS, NMCM, NMCB, and Depot Time rates (along with UPNR) will be affected by (LIMS-EV Data, 2013). Target aircraft availability has remained unchanged since 2009 (LIMS-EV, 2013).

The 2009 BCA used the benefit metrics of: normalized aircraft availability rate relative to fiscal year 2008 targeted goal, on-time delivery rate (original and revised), routine depot assistance request response time, indexed not mission capable supply rate, component product quality deficiency report rate, customer wait time, issue effectiveness rate, and stockage effectiveness rate (BCA: Executive Summary, 2009). While the overall construct of these metrics remained intact in this project, there were several changes. Grouped together, with the exception of on-time delivery rate, the remaining metrics of the 2009 BCA can all be measured with NMCM, NMCS, NMCB, and Depot Time rates. Furthermore, through measurement of these four metrics, the major factors of aircraft sustainment are assessed for their impact, cost, and necessity. In other words, over a long period of time, UPNR rates eventually go to zero for the specific aircraft as the maintenance status is specified or the disposition given. Routine depot assistance request response time is a measure of the time it takes a depot to assist with a maintenance disposition but there is anecdotal evidence to suggest this process is not used as routinely as envisioned due in part to the hours of operation at depots and their subsequent inability to furnish an answer over times such as weekends or late nights. From this, there is reason to believe routine depot assistance request response time does not completely correlate with actual needs for depot assistance. The component product quality deficiency report rate (PDQR) was not included in this project because PDQR rates impact NMCB and NMCS and consequently represent a factor measured in the 2009 BCA's benefit metrics of aircraft availability and non-mission capable supply rates. The remaining 2009 BCA benefit metrics of customer wait time, issue effectiveness rate and stock effectiveness rate are also components of indexed non-mission capable supply rate. Product deficiency rates fail to demonstrate mutual exclusivity since they impact NMCS,NMCB, and customer wait time.

Decision Analysis

Decision analysis is a tool for making decisions with multiple, competing factors. It represents a strategic method of assessing different decision criteria to inform decision-makers of the potential impact and consequences of alternatives. The essential element of a decision is the presence of alternatives (Kirkwood, 1997). It is therefore instrumental the decision criteria be mutually exclusive in order to produce alternatives. Value hierarchies represent tiers in a decision. Since there is no single metric to evaluate depot performance, aspects of the depot must be categorized by tier. Such a hierarchy is shown in Table 1: Aircraft Availability Sub-Factors. Aspects of aircraft availability are divided by tiers based on their applicable parts. Kirkwood describes this organization as a value hierarchy (Kirkwood, 1997). Aircraft Sustainment can be similarly broken into value hierarchies with activities broken into the sub-components. The sub-components, or tiers within the value hierarchy, should have certain desirable properties. These desirable properties represent extensive study of decision theory and are briefly described in the ensuing paragraphs. Kirkwood states the desirable properties for value hierarchies, those used in the 2009 BCA and the ones proposed by this project, are: Completeness, nonredundancy, decomposability, operability, and small size (Kirkwood, 1997).

Completeness is a measure of how well the metrics address pertinent concerns. It is necessary to know only how well an alternative performs in lowest-tier evaluation considerations assess its performance with respect to the overall evaluation consideration (Kirkwood, 1997). Kirkwood further states if all important evaluation considerations are not included, then evaluating alternatives may not be able to distinguish those of different preferability (Kirkwood, 1997). In simpler terms, if the metrics do not include all the important measures, the decision will likely be unable to achieve the desired objectives. Completeness of the metrics ensures all are considered and have a distinctive place in the decision analysis.

Nonredundancy is the second of the five desirable properties. Nonredundancy ensures no two evaluation considerations in the same tier overlap (Kirkwood, 1997). This is also an essential part of the hierarchal nature of the chosen metrics – the mere presence of the lower tier divides up the metrics above it with more detail (Kirkwood, 1997). On this point, the 2009 BCA used overlapping tiers of metrics to determine benefits for further analysis. Nonredundancy ensures each metric receives its desired and apportioned weight without being influenced by the weights of superior or subordinate metrics. Furthermore, the nonredundant decision criteria fit into precisely one category.

Decomposability, often referred to as interdependence, is the third of the five desirable properties. Decomposable decision criteria are not counted in more than one of the lower-tier considerations (Kirkwood, 1997). That is, when measuring criteria in one tier, it is inappropriate to then again measure its sub-components in another tier. A lack of decomposability causes skewed analysis when determining the overall preferability of an alternative (Kirkwood, 1997).

The fourth desirable properties is operability. Operability relates to an understandable and interpretable structure – both intuitive and logical in its structure and organization (Kirkwood, 1997). Operability is often a subjective term – some who lack the specialization or understanding of the criteria may not be able to readily interpret its inherent importance. Nonetheless, the decision criteria must still relate to the model used in order to be of any benefit – often causing those with less experience in the discipline to become confused. In the case of C-17A sustainment strategies, the operability of the decision criteria, or metrics, chosen are both generalizable across other aircraft and transferable to those strategies.

Lastly, small size is a desirable property of decision criteria. A relatively small number of decision criteria can be communicated more easily and further represent where tradeoffs can be made between decision criteria (Kirkwood, 1997). The small size preference also ensures only the most important and relevant information is considered (Kirkwood, 1997). Certainly, in sustainment strategies, there are innumerable details from decisions on economic order quantities of bench stock items to performance evaluation criteria for first, second, and third tier supply chain partners. However, the ultimate reflection of those decisions can be captured in an over-arching metric. The authors of this project argue those over-arching metrics are NMCS, NMCM, NMCB, and Depot Time rates for the entire fleet.

The use of decision analysis as a tool for further informing strategic decisions based on their ability to achieve desirable objectives is greatly enhanced though careful selection of decision criteria. According to Kirkwood, the desirable properties of those decision criteria are completeness, nonredundancy, decomposability, operability, and small size. This belief of this project is that the metrics chosen reflect these properties and create opportunities within this trade space for the consideration of alternatives with respect to the sustainment strategies.

III. Methodology

Chapter Overview

The purpose of this section is to detail the approach taken to assess the impact of different sources of repair on the sub-factors of aircraft availability. This project used a similar methodology as the 2009 BCA with respect to developing a decision analysis-based model to evaluate performance metrics for C-17A sustainment. The metrics chosen were the result of an in-depth review of the 2009 BCA, discussion with the C-17A Program Office at AFLCMC, senior leaders in the AFMC's AFSC, subject matter experts in depot maintenance, graduated aircraft maintenance squadron commanders, and doctorate level Operations Research faculty. Refined aircraft data was used in the model created to evaluate the impact different sources of repair, corresponding to different sustainment strategies, had on the sub-factors of aircraft availability.

Aircraft Selection and Sustainment Strategies

The aircraft chosen for this project were representative of the different sustainment strategies currently in use throughout the USAF with respect to tanker, airlift, and reconnaissance and surveillance aircraft. Variations of certain sustainment strategies were by either separating or combining aircraft models indicative of that sustainment strategy.

Of important note, two facts bear mentioning. First, the sustainment strategy and aircraft sustainment activities cannot be separated from each other. In other words, it would be difficult to know if the aircraft and its inherent maintainability are responsible for the aircraft availability sub-factor values or, whether those values are tied to the sustainment strategy itself. The project did not use normalized data for this reason as well. Though the 2009 BCA normalized data relative to a fixed standard, a different methodology was used for this project. Secondly, the only sustainment strategies assessed were the current ones in use. The 2009 BCA created sustainment options, then used extrapolated data to predict performance over a 30-year period. The limited options of sustainment strategies currently in use were defendable through data and therefore represented potential sustainment strategies to transition the C-17A to. Accompanying each aircraft is a short summary of the sustainment strategy in use.

E-8C

The Northrop Grumman E-8C Joint Surveillance Target Attack Radar System (J-STARS) was initially produced in 1997 (E-8C, 2012). The E-8C is based off a modified Boeing 707 airframe and has a distinctive 27 foot long radome along its underside housing a phased-array radar (E-8C, 2012). The E-8C conducts battle management and command and control missions in support of targeting operations. The E-8C was included in this project because it represents a performance based logistics (PBL) sustainment strategy in addition to organic depot activities. Northrop Grumman sustains the engines in conjunction with a prime contractor, Pratt & Whitney. Most recently, the E-8C has undergone a re-engining process to upgrade and its four turbofan engines. The majority of the re-engining work was conducted at Northrop Grumman’s Lake Charles, Louisiana Depot. The remaining sustainment activities occur at the WR-ALC (Northrop, 2013).

KC-10

The KC-10 Extender is the largest refueling aircraft in the world. In addition to its ability to refuel other aircraft, it has an extensive cargo mission. Based on the McDonnell Douglas DC-10 airliner, the KC-10 can carry 170,000 pounds of cargo (KC-10, 2011). The KC-10 was included in this project because it represents a larger scale PBL sustainment strategy. Currently, Northrop Grumman is responsible for: line replaceable units, test and support equipment, consumable parts, bench stock items, and flight line support and maintenance equipment (KC-10 Contractor, 2012). The remaining items of sustainment are primarily sourced at the WR-ALC. The E-8C represents a unique blend of PBL activities with certain functions performed at organic depots in order to maintain those capabilities within the government.

C-5A & B

The C-5A and B models were built in 1970 and 1986, respectively, by the Lockheed-Georgia Company (C-5A/B, 2012). The C-5 A and B are strategic airlift aircraft with a cargo capacity of 270,000 pounds. The C-5 A and B models were included in this project because they represent an organic sustainment strategy with ALC-directed sustainment activities (WR-ALC, 2011). The WR-ALC uses the same organic depots for upgrades and the modification program that takes a C-5A or B and transitions it into a C-5M through a two-phased process. Consequently, there are fewer C-5A and B model aircraft as there are increases to the C-5M fleet.

C-130E & H

The C-130E and H models were built in 1962 and 1974, respectively, by the Lockheed-Martin Aeronautics Company (C-130, 2011). The C-130 is a tactical airlifter with a cargo capacity of 36,500 pounds. The C-130E and H models were included in this project because they represent another aircraft using an organic sustainment strategy with different results from the organic sustainment strategy for the C-5. The WR-ALC coordinates or executes the coordination of all facets of C-130E and H sustainment. This program has existed with minor changes throughout the evaluation period for this project. The WR-ALC also conducts programmed and unscheduled depot level maintenance, coordinates contract and depot field teams, and organic and contractor support (330th ASG, 2008).

KC-135R

The KC-135R was initially delivered in 1957 by Boeing (KC-135R, 2011). Based on the Boeing 707, the aircraft is the cornerstone of the refueling fleet and can carry 83,000 pounds of cargo as well (KC-135R, 2011). The KC-135R was included in this project because it represents a contractor-based sustainment strategy. Recently transitioned to Boeing in conjunction with several other contractors in 1999, the KC-135R represents a significant sustainment strategy success as the average fleet age is 57 years and predicted to surpass 80 years before it is retired (KC-135R, 2011).

Benefit Model Description

The benefit model used in this project used the 2009 BCA as its basis. The weights represented prioritized values as previously described. The rate columns were populated with the average values for the specific metric assessed. Averages were taken from the specified duration and then placed into the cell corresponding to the aircraft within the sustainment type noted above the model. Individual averages were multiplied by the weighted value assigned to the particular benefit

The purpose of the benefit model is to assess the impact of different sources of repair on the sub-factors of aircraft availability. Historical data from several major weapons systems was collected from Logistics, Installations, and Mission Support – Enterprise View (LIMS-EV) and the Air Force Total Ownership Cost (AFTOC) databases. Historical data for the C-17A, C-5A, B, and M models, C-130E, H, and J models, KC-135 R, KC-10, and E-8A was collected from FY1994 to FY2013. Data over this period of time was analyzed for anomalies that may skew analysis and vetted for the impact of program transitions, maturity of the reliability curve, and number of aircraft in the fleet. Data previous to FY1994 was considered either too dated or unrepresentative of the current practices in the view of the authors of this project.

Several findings from this study led to the creation of business rules to guide the refinement of data, the exclusion of certain aircraft altogether, or the exclusion of certain years of aircraft data. Data for the sustainment strategies for the C-5M and C-130J aircraft were completely excluded for this project because of the significant amount of learning still in progress. Learning, in terms of maintainers, logistics, supply chain management policies and technical data development will eventually result in lower NMCS, NMCM, NMCB, and Depot Time rates. However, presently the sustainment strategy data these two programs are not yet representative of the program and therefore were not included. Data for the first five years after initial production and the first three years after a transition were excluded. Initial production exclusion accounted for the growth in the reliability of the aircraft and improvements in maintenance and logistics through learning. Data for the first three years after a transition to a new source of sustainment was also excluded to account for the transition costs. Lastly, the final three years of an aircraft's sustainment program data was excluded. This final three years of an aircraft program, such as the C-130E, demonstrates low fleet numbers and high amounts of cannibalization that are not indicative of the sustainment strategy previously used.

Data for C-17A, C-5A, and B, KC-10, KC-135R, E-8C, and C-130 E, and H models were imported into MS Excel® arranged by fiscal year. Columns were added for NMCS, NMCM, NMCB, and Depot Time rates. All columns for NMCS, NMCM, NMCB, and Depot Time rate data were then averaged as a percentage rate for the entire duration of fiscal years assessed (see Appendix B, Table 2 for individual metric formulas).

The development of the weight for NMCS was derived from the 2009 BCA by totaling the percentage of supply-related functions, discussing appropriate weighted values with the C-17A program office at WR-ALC, graduated maintenance squadron commanders, and senior leaders at the Air Force Sustainment Center (AFSC). Each of these aircraft availability sub-factors was multiplied by a specified weight to show the average weighted impact for the sustainment program. All the metrics related to a derivative of the supply function were totaled for their relative importance to the whole model. The summation of all the derivatives of the supply function from the 2009 BCA was 42.2%. This approximate percentage was reflected in the model this project proposes resulting in a value of 40% assigned to the derivative of the supply function.

The proportionate value was maintained relative to the other sub-factors of aircraft availability used in this model. The weight for NMCM was evaluated to 75% as important as NMCS. The resulting weight for NMCM was 30%. The weight for NMCB was not addressed in the 2009 BCA. Consequently, the weighted value of this metric was subject to discussions within the academic environment, between several maintenance experts having successfully completed command of an aircraft maintenance squadron, senior leadership from the Air Force Sustainment Center, and lastly, from the C-17A Program Management Office at the AFLCMC. The resulting weight was established at 10%. The weight for Depot Time was also not addressed in the 2009 BCA and underwent the same assessment as the NMCB weight. The resulting weight for Depot Time rate was 20%. Further development of weights should be informed by senior leaders based on strategic priorities.

Sensitivity analysis was then performed on the model. The results of the sensitivity analysis are found in Figure 2 below. The sensitivity analysis performed sought to keep the same proportion of weighted values intact as they were either added or subtracted to the weights. Specifically, for every 4-point increase in the value of NMCS, there was a corresponding decrease in the values of NMCM, NMCB, and Depot Time rates by 3 points, 1 point and 2 points, respectively. This process was repeated until a change occurred in the sustainment option with the lowest calculated value. After excluding the C-130J program because its Depot has only been in operation since May, 2011, the only other programs possessing lower values for the sub-factors measured were the KC-10 (NMCB rate and Depot Time rate) and the C-130E & H models (Depot Time rate only).

IV. Analysis and Results

Chapter Overview

The results of analyzing NMCS, NMCM, NMCB, and Depot Time rates are shown in Figures 3 through 6. These figures represent charts of aircraft-specific rates from data collected over the described period. Figures 7 through 11 show the individual aircraft raw data used to complete this analysis with shaded regions representing data excluded from analysis.

This project found the best strategy, according to the benefit model only, to reduce the rates of NMCS, NMCM, NMCB, and a Depot Time rate was the current sustainment program for Option 1 in Figure 2, the C-17A. It represents the best performing sustainment strategy in terms of benefits. However, cost analysis, risk assessment, or incentive structure analysis has yet to be accomplished to accompany these results. Until the completion of research to fully inform the next BCA, the resultant best-value strategy is not known.

Table 1: Benefit Metrics

Benefits Metric	Weights		Option 1 PSM/PSI C-17A (PSM/PSI)	Option 2A PBL E-8C (PBL)	Option 2B PBL KC-10 (PBL)	Option 3A Organic C-5A,B (Organic)	Option 3B Organic C-130 E,H (Organic)	Option 4A Contractor KC-135R (Contractor)
Percent Non-Mission Capable Maintenance Rate (NMCM)	30.00%	Rate	0.0906	0.0971	0.1001	0.1824	0.1160	0.1096
		Weighted Result	0.0272	0.0291	0.0300	0.0547	0.0348	0.0329
Percent Non-Mission Capable Supply Rate (NMCS)	40.00%	Rate	0.0209	0.0368	0.0254	0.0508	0.0286	0.0294
		Weighted Result	0.0083	0.0147	0.0102	0.0203	0.0114	0.0118
Percent Non-Mission Capable Both Rate (MNCB)	10.00%	Rate	0.0150	0.0171	0.0137	0.0744	0.0670	0.0342
		Weighted Result	0.0015	0.0017	0.0014	0.0074	0.0067	0.0034
Depot Time Rate	20.00%	Rate	0.1433	0.2689	0.1410	0.1738	0.1054	0.1488
		Weighted Result	0.0287	0.0538	0.0282	0.0348	0.0211	0.0298
Sum of individual metrics weighted results			**0.0657**	**0.0993**	**0.0697**	**0.1172**	**0.0740**	**0.0778**
		Rank Order	**1**	**5**	**2**	**6**	**3**	**4**
	FY Begin		FY98	FY01	FY94	FY94	FY02	FY99
	FY End		FY13	FY13	FY13	FY13	FY13	FY13
	Fleet Size FY13		217	17	59	31(A)/31(B)	6(E)/265(H)	362
	Average Fleet Size		135	17	59	56	221	356
	Years Since Milestone C		20	15	32	43(A)/27(B)	51(E)/39(H)	57

Results of Sensitivity Analysis

Two key principles were applied to the sensitivity analysis. First, there were only two aircraft sustainment programs with benefit metric values less than Option 1, the C-17A. Those programs with lower benefit metric values were Options 2B, the KC-10 and Option 3B, the C-130 E and H model sustainment programs. The KC-10 NMCB and Depot Time rates were lower than the C-17A and the C-130 E and H models had lower Depot Time rates than the C-17A as well. No other programs expressed lower values of the four metrics assessed. Consequently, no change in the weighted values would cause those programs with higher values to become lower than the C-17A. From this finding, sensitivity analysis focused on those two programs, excluding all others, and sought to determine how much the NMCB and Depot Time weights needed to be changed in order to produce a different result in the model.

The summation of weights totaled 100% and corresponding changes to the weights associated with the sensitivity analysis did not exceed one hundred percent. Changes were taken incrementally to affect the overall results of the analysis. By changing the weighted values associated with the benefit metrics, certain values were noted which would change the results and conclusions of this analysis. The initial weighted values were reduced by three percent for NMCS rate and four percent for NMCM rate, while the weighted values were increased by three percent and four percent for NMCB rate and Depot Time rate, respectively. The values, as assigned from the study, their corresponding rank orders in terms of lowest value, and the values needed to change these recommendations are found in the figure below (Figure X-X). Under no weighted combination did the sustainment program embodied by the C-130E and H models outperform the C-17A overall. Those sustainment programs without any values less than the C-17A sustainment program were removed from the sensitivity analysis and are represented by “grayed-out” sections with bold “X’s”. Additionally, the highlighted cells were the only cells with values less than those observed by the C-17A sustainment program. The sensitivity analysis sought to determine what the overall weights had to be in order for these sustainment strategies to outcompete the current C-17A sustainment program.

Table 2: Sensitivity Analysis

Benefits Metric	Weights		PSM/PSI Option 1 PSM/PSI C-17A	PBL Option 2A PBL E-8C	PBL Option 2B PBL KC-10	Organic Option 3A Organic C-5A,B	Organic Option 3B Organic C-130 E,H	Contractor Option 4A Contractor KC-135R
Percent Non-Mission Capable Maintenance Rate (NMCM)	9.00%	Rate	0.0906	0.0971	0.1001	0.1824	0.1160	0.1096
		Weighted Result	0.0082	0.0087	0.0090	0.0164	0.0104	0.0099
Percent Non-Mission Capable Supply Rate (NMCS)	12.00%	Rate	0.0209	0.0368	0.0254	0.0508	0.0286	0.0294
		Weighted Result	0.0025	0.0044	0.0030	0.0061	0.0034	0.0035
Percent Non-Mission Capable Both Rate (MNCB)	31.00%	Rate	0.0150	0.0171	0.0137	0.0744	0.0670	0.0342
		Weighted Result	0.0046	0.0053	0.0042	0.0231	0.0208	0.0106
Depot Time Rate	48.00%	Rate	0.1433	0.2689	0.1410	0.1738	0.1054	0.1488
		Weighted Result	0.0688	0.1291	0.0677	0.0834	0.0506	0.0714
Sum of individual metrics weighted results			0.0841	0.1475	0.0839	0.1290	0.0852	0.0954
		Rank Order	2	6	1	5	3	4
	FY Begin		FY98	FY01	FY94	FY94	FY02	FY99
	FY End		FY13	FY13	FY13	FY13	FY13	FY13
	Fleet Size FY13		217	17	59	31(A)/31(B)	6(E)/264(H)	362
	Average Fleet Size		135	17	59	56	221	356
	Years Since Milestone C		20	15	32	43(A)/27(B)	51(E)/39(H)	57

The figure shows one possible change required in the values for the weighted benefit metrics required in order to achieve alternate outcomes. The sensitivity analysis shows significant changes in the values of metrics in order to drive changes in the model. This dramatic change in weighted values demonstrates the dominance of the current sustainment strategy's performance over those in the comparison across all aspects of sub-factors.

Investigative Questions Answered

The research questions posed in this study sought to provide both the justification of the study and segue into the creation of alternate sustainment performance metrics to incorporate into future business cases analyses. The answers to the questions found in the Section I: Research Questions, drove much of the analysis, framing, findings, and ultimately the results and conclusions of this study.

The first investigative question centered on the mutual exclusivity of the benefit metrics used in the 2009 BCA. In order for a criterion to be mutually exclusive it must not be assigned to more than one category. A criterion is assigned to more than one category effects on each category thus reducing the margin of difference between criteria. When a decision criterion exhibits mutually inclusive traits, the causal impact cannot be determined. A single trait shared among decision criteria, in the case of the 2009 BCA, the benefits metrics, cannot be separated from other decision criterion sharing that same trait. Despite different terminology and the fit with what Ammons (1996), Kaplan (1993), and Brown (1996) deem as necessary attributes for evaluating performance measures, the 2009 BCA benefits metrics are clearly mutually inclusive. Simply put, from the metrics chosen, there is no reason to believe a broken part off the shelf at the depot will not require a new part to be ordered, increasing customer wait time, decreasing stockage effectiveness rate while driving up the overall time the weapons systems in non-mission capable for supply and degrading the aircraft's availability. The mutually inclusive trait across all these decision criteria was the single part needed to make the aircraft operational. One measure for the supply function would be sufficient to capture this occurrence while preventing a stockout or deficient part from impacting several other decision criteria.

From the 2009 BCA, the method used to calculate Normalized Aircraft Availability Rate Relative to the Aircraft Standard represented the percentage of aircraft not in a depot status or in a non-mission capable status. The formula for determining aircraft availability is: Aircraft Availability = 100% – NMCS rate – NMCM rate – NMCB rate – Depot Time – UPRN rate. Using aircraft availability in addition to its sub-factor as another metric result in an interaction between these decision criteria that skews analysis. The same holds true for Customer Wait Time. As NMCS rates decrease, Customer Wait Time decreases based on the availability of parts or supplies – the very factor influencing NMCS rates. Additionally, NMCS rates exhibit interactions with Issue Effectiveness Rates since the common factor between the two is number of backordered parts. As NMCS Rates decrease based on fewer backorders, Issue Effectiveness Rates also decrease based on fewer backorders. Stock Effectiveness Rates are prone to same sub-factor interference as NMCS Rates due to the shared backorder metric.

Of the metrics used in the 2009 BCA, there are only three factors which do not exhibit some degree of sub-factor interaction: ON-Time Delivery Rate (Original and Revised), Routine Depot Assistance Request Response Time, and Component Product Quality Deficiency Report Rate. The remaining five metrics used in the 2009 BCA use mutually inclusive metrics with varying impacts throughout each of the metrics and therefore, throughout the entire analysis and should not be used together.

The second research question focused on the 2009 BCA weights and their source for determination. The 2009 BCA weights were determined using a survey of air logistics center (ALC) subject matter experts. Strategic stakeholders assigned weights indicative of their perceived priority of the individual benefit metric. The rigor and the academic integrity of the process for assigning priority and weights are both appropriate and correctly used. This represents a considerable strength in the 2009 BCA methodology in its ability to survey individual stakeholders and subject matter experts.

The third research question focused on the correctness of the weights used in the 2009 BCA. From discussion with subject matter experts, there is reason to believe the intentionally higher priority given to the supply function is both appropriate and corresponds to intuitive logic regarding sustainment. If parts are available for trained maintainers to use, aircraft will likely spend less, if any, time in a NMCS status and only be recorded in NMCM rates as the part is appropriately used. Should the supply function be impeded, aircraft will tend to spend more time in NMCS status followed by a period of time in an NMCM status while being repaired.

The fourth research question posed sought to determine which metrics could best assess the impact on aircraft availability given changes in the source of repair. To determine which metrics best assess sustainment source performance, the measures of sustainment broadly capturing those activities pertinent to aircraft longevity and availability should be used. As evidenced with such initiatives as the C-130 High Velocity Maintenance (HMV), there have been decreases observed in NMCS, NMCB, and Depot Time rates when efforts to decrease these very metrics become part of the sustainment strategy (Scully, 2009). Sustainment is directly tied to aircraft availability. Long-term solutions to keep aircraft flying are the cornerstone to sustainment strategies. Aircraft availability focuses on reducing the effects of five factors, or decision criteria, seeking to find a sustainable balance between them. The five factors related to aircraft availability are: NMCS, NMCM, NMCB, UPNR, and Depot Time Rates. This project chose to use the major sub-factors of aircraft availability to assess sustainment performance. The only factor used to calculate aircraft availability not incorporated into the model was UPNR. Unit possessed not reported was excluded from the model based on the short-lived duration of the status and the high potential for this metric to exhibit sub-factor interference with other metrics used. An aircraft awaiting a decision on the specific part number required for a fix or an aircraft with a new problem, previously unseen or unanticipated by the maintenance function will enter into the UPNR status while the specific part or maintenance action (or both) is determined. Aircraft in UPNR status represent a method to still count that specific aircraft against aircraft availability while NMCS, NMCM, NMCB, or Depot Time status is assigned. The model and data exclusion also sought to minimize the impact of this specific status insofar as eliminating the time until the weapon system matured along the reliability growth curve where UPNR rates are observed to decrease with the maturation of the weapon system and improved training and diagnosis practices.

The final research question sought to determine the appropriate sources of data for sustainment strategies. Once the metrics were chosen and validated for mutual exclusivity, data sources were explored to ensure standardization and compatibility with the model. The LIMS-EV database was used to retrieve validated data on the entire fleet of Air Force aircraft starting from fiscal year 1991. Previous years' data was both not available and also not reflective of current sustainment practices in use today.

Summary

The research questions represented a framework for this study to guide research and the development of the model. From the DoDIG report, there was a specific need for a comprehensive BCA. The 2009 BCA, though representative of progress toward this option, ultimately fell short of achieving its directed purpose of analyzing all alternatives to determine the best-value sustainment option.

V. Conclusions and Recommendations

Discussion

The purpose of this project was two-fold: to develop mutually exclusive BCA benefit metrics to assess sustainment strategies and to develop a model to use within a decision analysis framework to inform future BCAs. This research represents the first phase in the construction of the next BCA as corresponding research will work to provide risk assessments and associated costs to complete such analysis. The intent of this research is to begin to develop a defendable methodology to conduct the BCA for the C-17A by providing a potential means for capturing performance benefits from one aircraft type and transferring them to the C-17A by adopting or adapting those policies and structures responsible for the desired performance. Furthermore, one potential for future research is the creation of real-time data display in the form of a Continuous BCA to inform budgetary decisions for all aircraft.

Conclusions of Research

In conclusion, this research found four mutually exclusive performance metrics for consideration in the next business case analysis. Those metrics: NMCS. NMCM, NMCB, and Depot Time rates were assigned weights based on the 2009 parent document, academic research and advisement, C-17A Program Management Office analysts as well as input from the Air Force Sustainment Center senior staff. The model generated from this research found the current sustainment strategy as the most beneficial in terms of performance across the metrics measured.

Significance of Research

The objective of this research is to improve upon a robust 2009 BCA. Mutually exclusive metrics have the best chance of delineating between different options where valuable decisions within the trade space can be decided. When used in a decision analysis framework, the absence of sub-factor interference allow for the evaluation of the merits of the independent metrics.

Though the results of this project are applicable only to the C-17A, there is potential for generalizability to other airframes. The 2009 BCA aided in informing the weights of the benefit model used. Additional research, discussion, and surveys may be needed to provide more input to the specific weights used in the model. However, from the sensitivity analysis, there is reason to believe significant changes in the weights are unlikely to produce different results should those weights be changed as they relate to different aircraft and models. It should also be noted the transition of the C-17A to a different sustainment program may negatively impact the sub-factors of aircraft availability for a period of time observed by this project to be up to three years if trends follow previous transitions in sustainment strategy.

Recommendations for Future Work

While this research represents only the performance benefits of certain sustainment structure, future research should include aspects of sustainment that do not involve determining the appropriate mix of government and contractor activities. Future research should also include analysis of incentive programs and their potential to affect cost savings while targeting specific performance standards. Of note, exceeding performance standards may not represent the best-value option for C-17A sustainment with regard to cost – the excess expenditures of resources to exceed standards may also represent areas for future savings while continuing to maintain readiness and aircraft availability. Moving forward from this research, certain incentive strategies and structures should be discussed in order to improve on the already remarkable performance record of C-17A sustainment while realizing the imperative for cost savings.

The next step is to re-assess the risk metrics associated with C-17A sustainment using mutually exclusive decision factors then complete the cost analysis portion to complete the next BCA. Cost analysis should provide easy to follow assessments of cost impacts to decision variables and present a range of costs associated with each sustainment option with standards of describing cost in net present value or in base-year fiscal dollars. The next BCA should leverage available databases to provide routine updates, concurrent with regularly scheduled inputs, to generate a Continuous BCA. When successfully completed, the next BCA can allow USAF senior leaders to:

- Analyze alternatives before proceeding with further sustainment decisions regarding the C-17A.
- Create projections on future benefits, costs, and risks to C-17A sustainment

- Further inform the five-year development plan (FYDP) and program objective memorandum (POM) to align budgeting decisions with sustainment objectives

Recommendations for future research will both compliment and build upon this research with the intent to provide senior leaders with the necessary tools to aid in sustainment decisions. This research centered around informing the next business case analysis and to that extent, more research needs to be directed in completing the risk, cost, and incentive models and to delve further into options for long-term engine maintenance and support.

Continuous BCA

Business case analyses are most valuable when they can be updated and compared to previous work and analysis. Comparisons can identify trends and expose areas for improvement by changing inputs. Current guidance requires BCAs be performed every five years to determine fiscal and sustainment progress, issues, and concerns as well as serving to update previous assumptions on the environment. These BCAs are costly and when not inclusive of mutually exclusive metrics, fail to capture the full spectrum of sustainment courses of action. A recommendation for future research follows four phases. First, the risk assessment from the 2009 BCA must be updated and matched to the performance benefits suggested by this research. Next, the cost metrics must be re-assessed on the appropriate blend of government-contractor activities mix for next BCA. Incentive structures should be studied to look specifically at maintaining the current sustainment activities while managing the contractor differently in order to realize the required cost savings directed for the program. Lastly, a Continuous BCA should develop from these four products: cost estimates, risk analysis, and incentive program structures. The Continuous BCA should leverage existing data systems, exporting information when routine updates are made, to populate an interactive display allowing for the simultaneous depiction of all benefit, cost, and risk metrics as well as incentive changes in addition to a future projection given historical data. Comparative analysis could project expenses given certain detailed incentive programs such as the standard firm, fixed incentive program but also include cost-plus. The Continuous BCA can then be used to inform the five-year development plan (FYDP) and the program objective memorandum (POM) process. The Continuous BCA would represent an additional tool used by senior leaders to evaluate the impact of performance, cost, and risk on sustainment strategies.

Competition of C-17A Engine Sustainment

Further analysis should assess the BCA's suggestion to compete the Pratt & Whitney FW-117 engines. The assumed cost savings identified was $1.6B though this assertion not neither supported with data nor accompanied a method for transition. The largest potential for cost savings contained no inclusion of costs relating to the workforce designed to determine a transfer plan. Consequently, much of this projected savings may no longer be available. In line with previous recommendations, consider other cost-incentives instead of seeing an alternate source of sustainment for the C-17A engines.

Incentive Analysis

From the model, the current sustainment strategy results in the lowest NMCS, NMCM, NMCB, and Depot Time rates. Changing the weights to favor Depot Time up to almost 50% of the model's total weight is the only manner for an alternate program to be as competitive as the C-17A's current sustainment strategy. Additionally, transitioning the program to an alternate, potentially less productive sustainment strategy may result in higher aircraft availability sub-factor rates. The lack of a credible alternative sustainment strategy makes a stronger argument for managing the contractor differently through incentives.

In 2007, the Center for Strategic and International Studies released a report intended to further inform the discussion of cost-plus contracts in the DoD. This report offers several different alternatives to cost-plus incentive structures. A full BCA may not reveal best-value decisions from re-allocating sustainment activities. The mix of Government and contractor activities should also be contrasted with analysis of incentives. Currently, the C-17A aircraft availability rates are higher than goal standard. Transitioning the program to a different sustainment strategy may incur sub-standard performance and not represent areas for significant savings. However, moving away from the cost-plus incentive structure may represent opportunities for savings without negatively impacting aircraft availability.

Summary

After 20 years of service, the C-17A consistently demonstrates some of the highest levels of aircraft availability of any aircraft in the USAF inventory. A 2006

DoDIG report directed the creation of a BCA to determine whether this performance was matched to best-value analysis. In order to fully inform discussions on best-value sustainment strategies a BCA should be able to quantify exceeding aircraft availability standards means in terms of cost and risk. Determining the appropriate balance of trade offs can only be made once the sustainment decision is fully informed. A thorough and complete BCA is the one of the most important steps in this assessment and one that needs to be carefully considered and created.

The 2009 C-17A BCA recommendations positively affirmed a government-led collaboration between the Air Force and The Boeing Company as the best-value solution for C-17 sustainment (BCA Executive Summary, 2009). This recommendation follows current legal requirements set forth in 2008 by the United States Congress requiring government-led integration support (need citation of this law). Furthermore, the recommendations also positively contributed to the Air Force's goal of maximized aircraft availability through incentives given for performance and the reduction of unavailability based on maintenance, supply and depot issues.

Overall, the 2009 BCA assessed seven potential cases for consideration. The cases were constructed according to integrator type and support provider. Furthermore, they were evaluated according to their ability to attain certain specific and measureable attributes relating to depot performance. These attributes were compiled then prioritized from subject matter experts examining workload assignments relative to pre-defined criteria. Following the analysis, the BCA set forth three courses of action, recommending one case as the best value of benefits, cost, and risk. From the recommendation of the BCA, the US Air Force, acting on behalf of the other governments in partnership with the

C-17A fleet, made several changes to the recommendation. The changed recommendation was then presented to The Boeing Company (hereafter referred to as Boeing). Boeing offered to meet the cost savings requirements without transitioning to the recommended course of action. The Boeing offer represented the status quo with continued efforts to reduce costs and realize performance improvements. The current state of affairs notes little change to the 2009 environment with the exception of the government acting as the primary source manager with the addition of an ongoing effort to transition the engine.

This project developed mutually exclusive BCA benefit metrics to assess different sustainment strategy benefits and developed weights to use within a decision analysis framework to better inform future BCAs. Depot sustainment strategies were compared using mutually exclusive metrics. This comparison was made to determine how each weapons system addresses sub-factors of aircraft availability. Business rules were applied to collected data. These business rules excluded data unrepresentative of the sustainment strategy and also informed future transition decisions. Current sustainment strategies were used as potential options for transitioning the C-17A program.

The current C-17A sustainment strategy appears to offer the best benefit when compared to the alternatives considered in this project. The C-17A has the lowest combination of sustainment sub-factors. Regardless of the importance placed on specific attributes, or the value of specific weights, the C-17A out-performs other sustainment strategies analyzed in the benefit model overall. The cost, risk, and incentive analysis will further inform whether the current sustainment strategy is the best-value decision and may reveal potential for cost savings.

Appendix A: List of Figures

Statistical Summaries

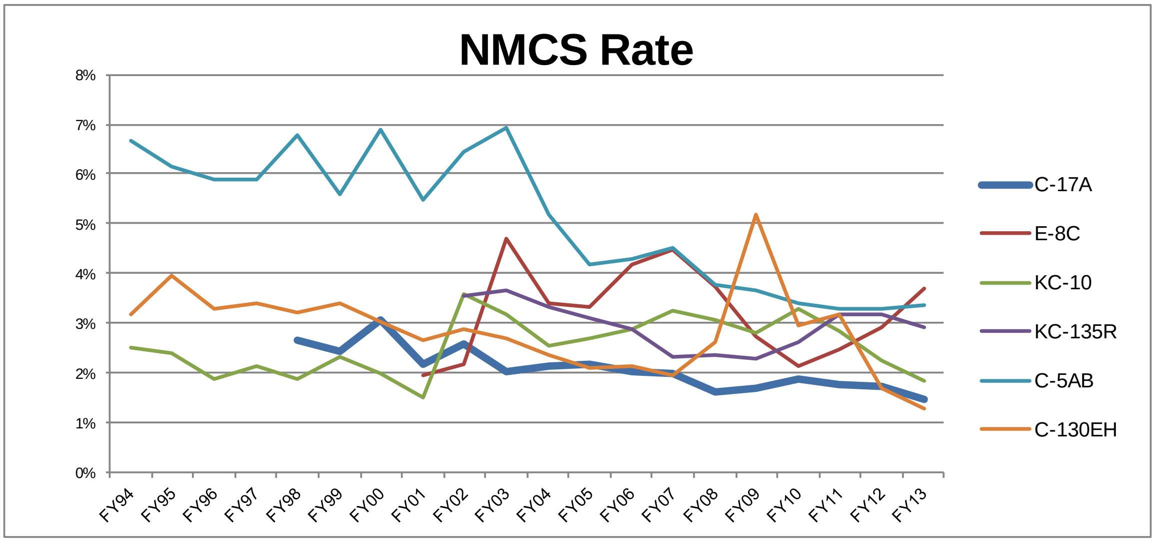

Figure 3: Percent Non-Mission Capable Rate for Supply

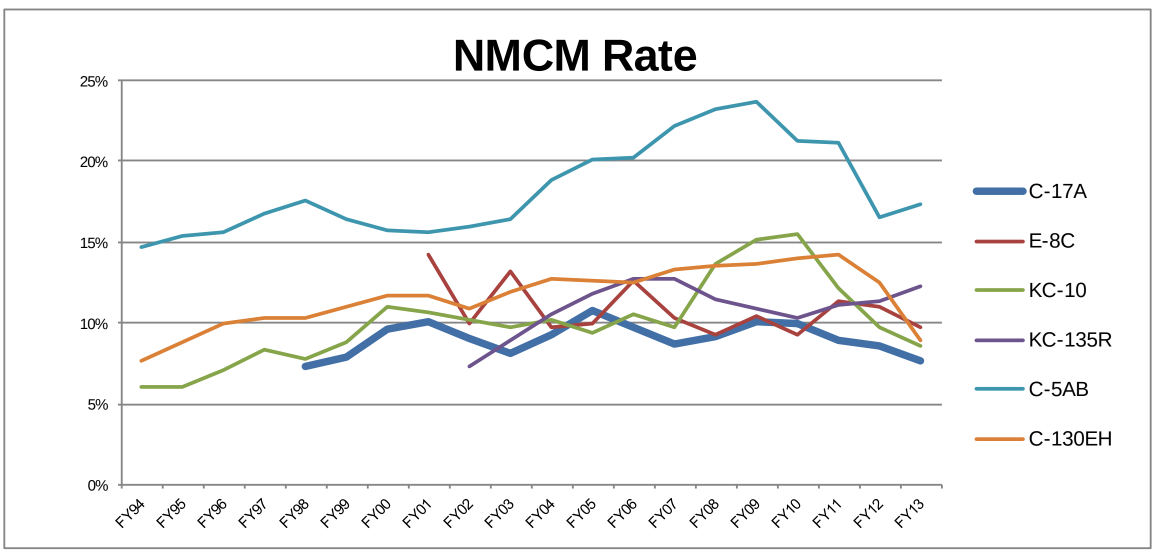

Figure 4: Percent Non-Mission Capable Rate for Maintenance

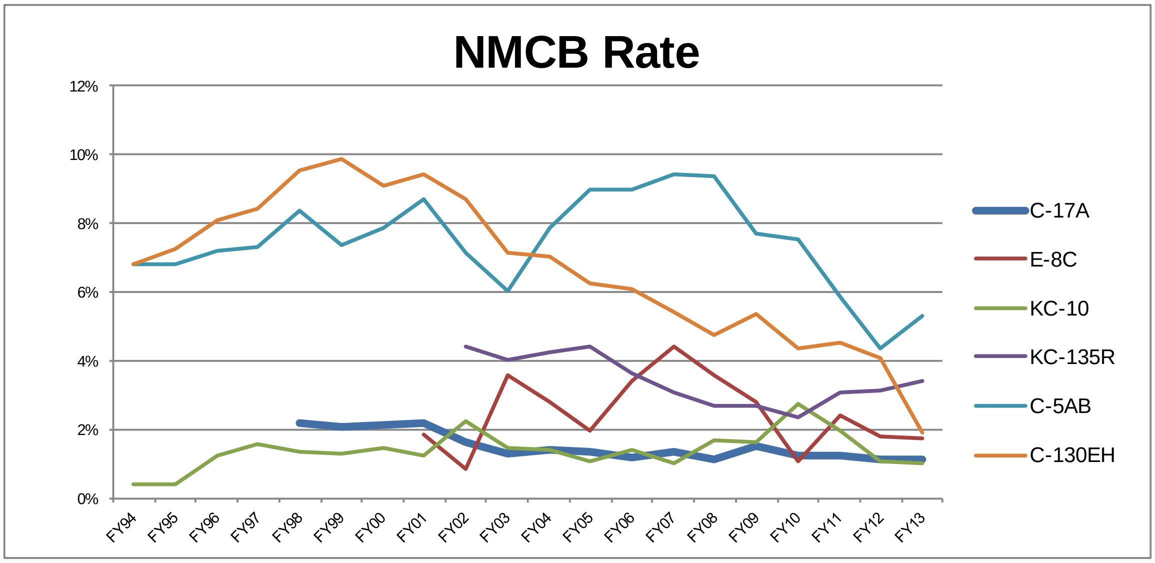

Figure 5: Percent Non-Mission Capable Rate for Both Supply and Maintenance

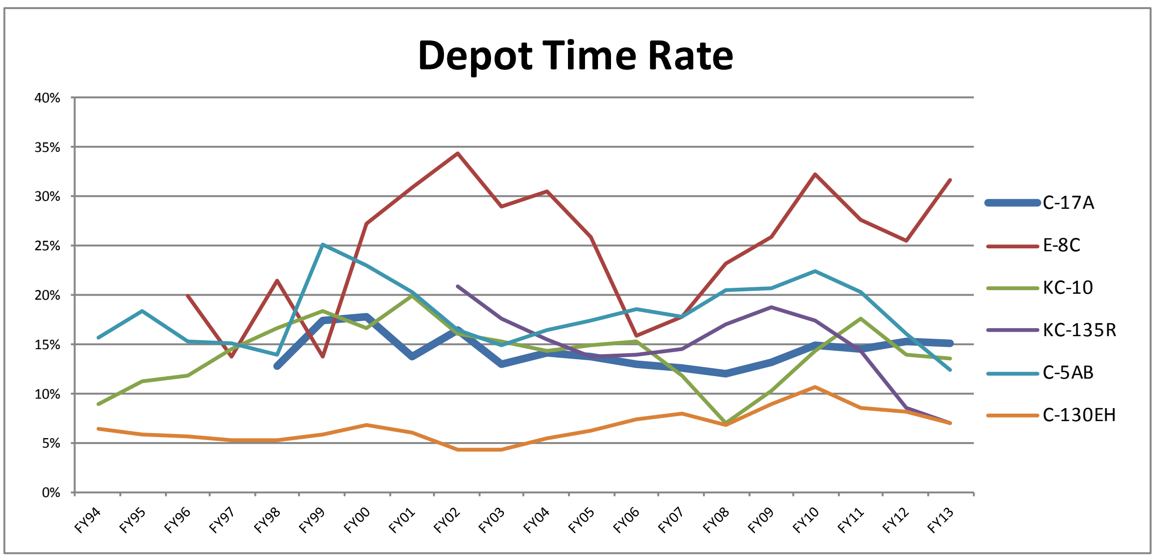

Figure 6: Percent Depot Time Rate

Excluded Data

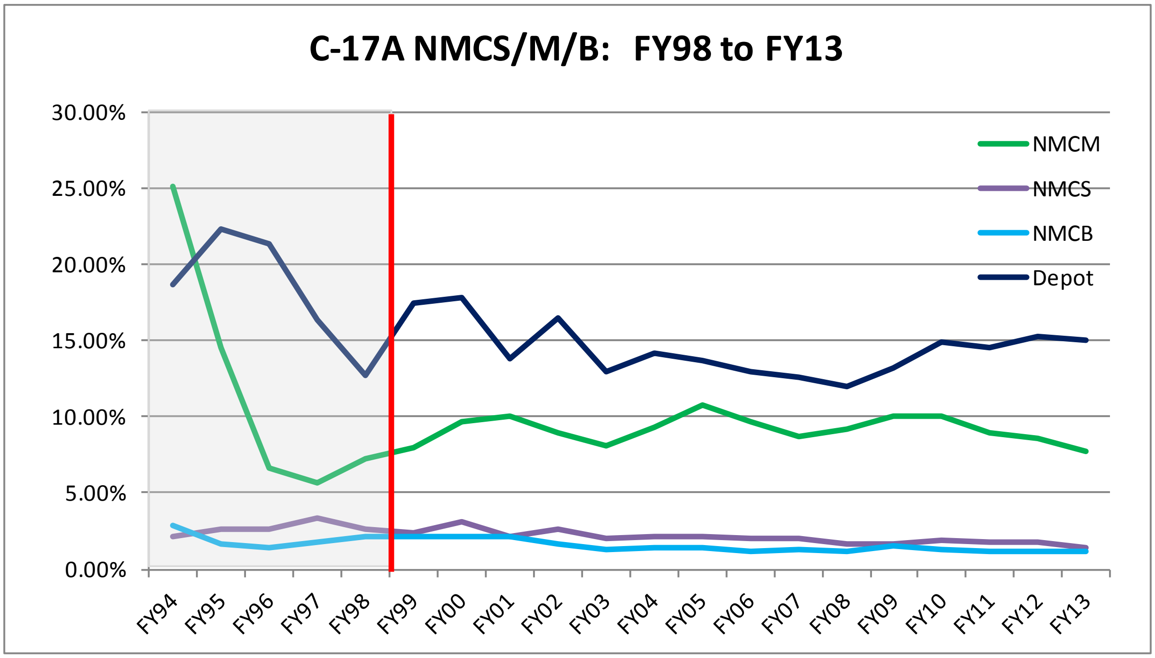

Figure 7: C-17A NMCS/M/B & Depot Time Rates

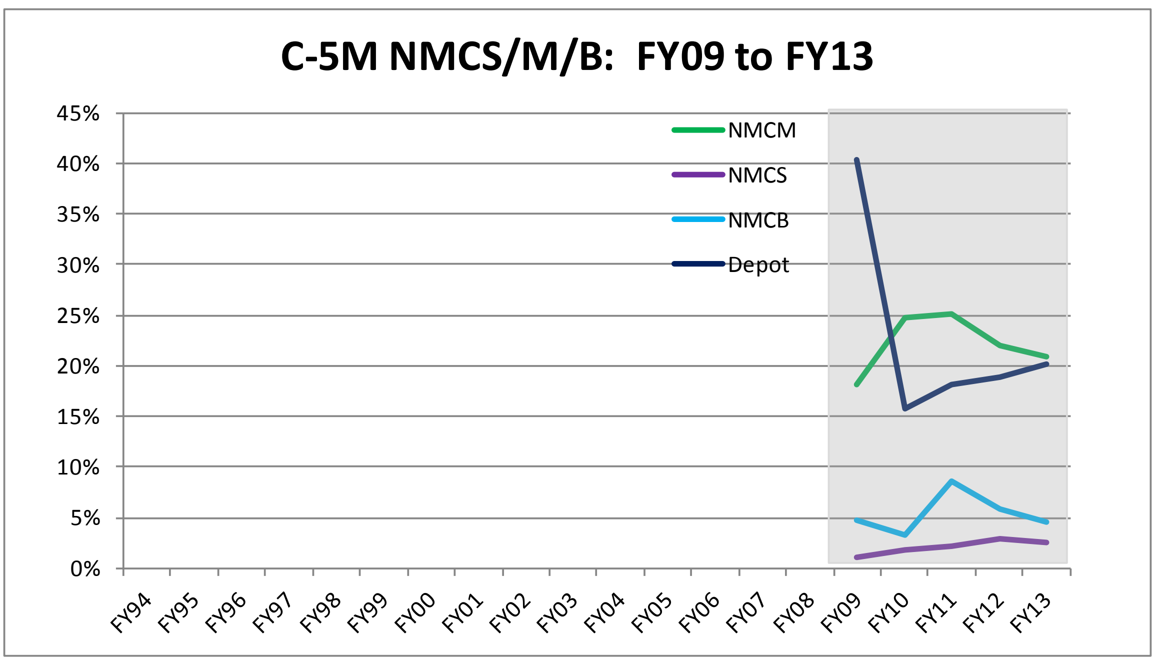

Figure 8: C-5M NMCS/M/B & Depot Time Rates

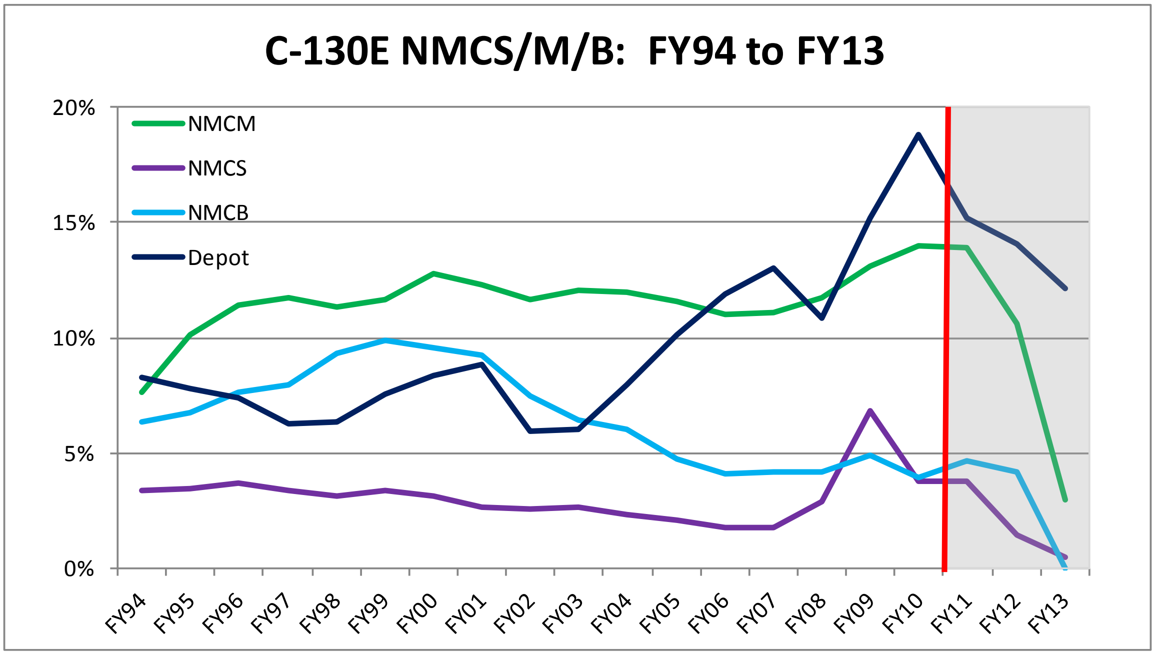

Figure 9: C-130 E NMCS/M/B & Depot Time Rates

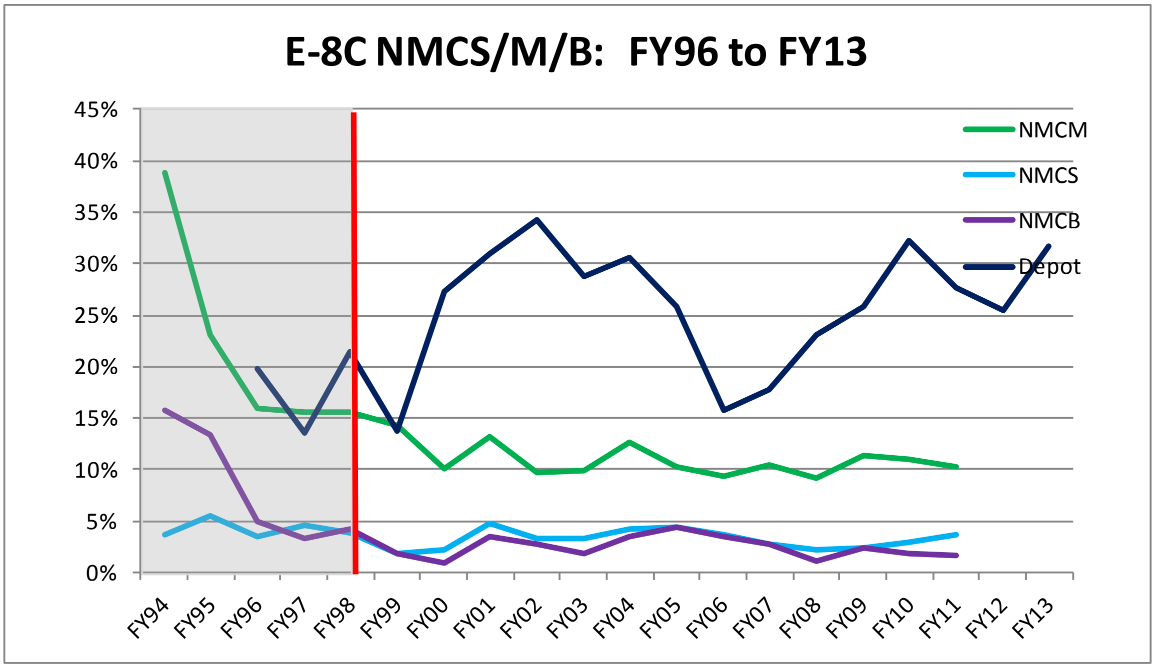

Figure 10: E-8C NMCS/M/B & Depot Time Rates

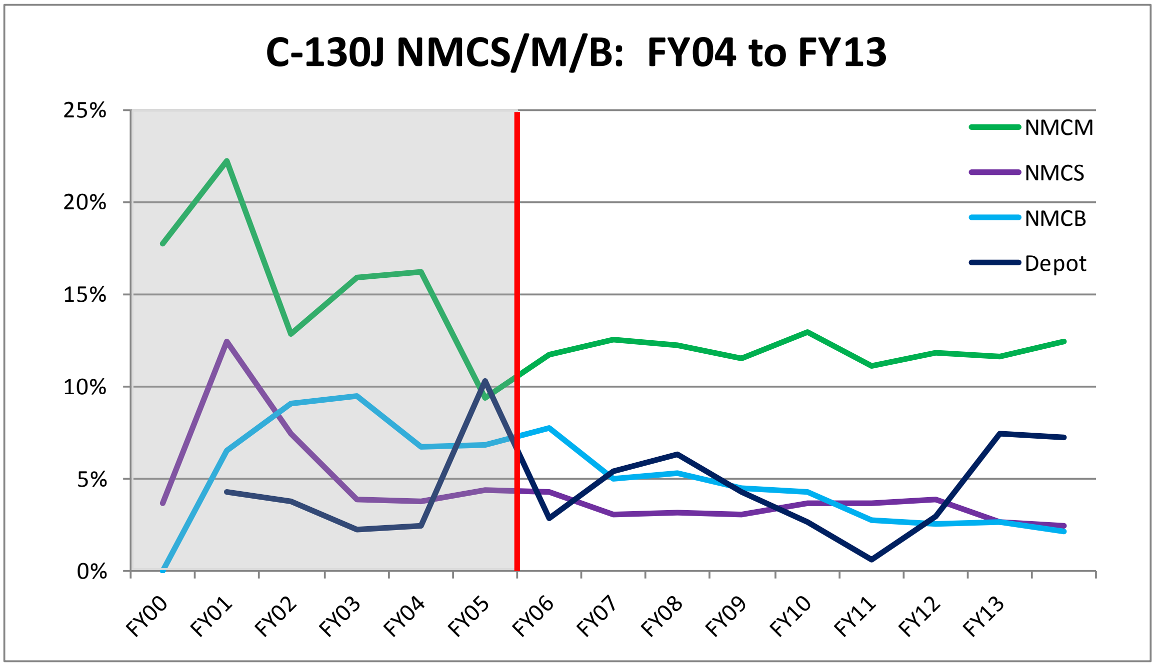

Figure 11: C-130J NMCS/M/B & Depot Time Rates (shaded region shows Business Rules applied though none of this program data was used in the final analysis).

Appendix B: List of Tables

Table 3: List of Acronyms and Definitions

NMCS – Non-Mission Capable for Supply	Percentage of aircraft that cannot perform any assigned missions because of a supply condition(s).
NMCM – Non-Mission Capable for Maintenance	Percentage of aircraft that cannot perform any assigned missions because of a maintenance condition(s).
NMCB – Non-Mission Capable for Both	Percentage of aircraft that cannot perform any assigned missions because of a supply and maintenance condition(s).
UPRN – Unit Possessed Not Reported	Percentage of aircraft/equipment that is unit possessed not reported is downtime when the unit still possesses the equipment but is not charged with the downtime.
TAI – Total Aircraft Inventory	The total number of aircraft possessed in the Air Force Inventory for that particular model type and designation.
Depot Rate	Percent of aircraft/equipment possessed by a depot (government/contractor facility) or depot field team.

Table 4: List of Formulas

NMCS Rate: $$\frac{NMCS\_hours}{TAI\_hours} \times 100$$

NMCM Rate: $$\frac{NMCM\_hours}{TAI\_hours} \times 100$$

NMCB Rate: $$\frac{NMCB\_hours}{TAI\_hours} \times 100$$

Depot Time Rate: $$\frac{Depot\_hours}{TAI\_hours} \times 100$$

TAI Rate: $$\frac{TAI}{TAI\_possessed\_hours} \times 100$$

UPRN Rate: $$\frac{UPNR\_hours}{TAI\_hours} \times 100$$

PDQR Rate: $$\frac{Deficient\_Parts}{TAI\_hours} \times 100$$

Table 5: Current Performance Standards and Observations (June, 2013)

C-17A Metrics: 2013 Performance vs. Standards	
Available (%) Projection	74.80%
Available (%) Standard	72.90%
Available (%)	74.14%
Depot (%) Projection	14.80%
Depot (%)	15.05%
UPNR (%) Projection	0.80%
UPNR (%)	0.51%
NMCS (NA) (%) Projection	1.50%
NMCS (NA) (%)	1.46%
NMCM (NA) (%) Projection	9.30%
NMCM (NA) (%)	7.74%
NMCB (NA) (%) Projection	1.20%
NMCB (NA) (%)	1.11%
MC (%) Standard	87.50%
TNMCM (%) Standard	9.40%
TNMCS (%) Standard	7.00%

Bibliography

Aerospace Sustainment Directorate: Mission Brief. 2012. http://www.wrcoc-aic.org/Archive/RS/RS10/RS10_ASD.pdf

Air Force Instruction 65-509 "*Business Case Analysis.*" September 19, 2008. http://static.e-publishing.af.mil/production/1/saf_fm/publication/afi65-509/afi65-509.pdf.

Air Force Maintenance Metrics. AFD -100105-055: Air Force Logistics Management Agency. March 20, 2009.

Air Force Total Ownership Cost (AFTOC) Database. March 1, 2013. https://aftoc.hill.af.mil/

American National Standards Institute (ANSI). http://www.ansi.org/ Accessed 15 Dec 2002.

Ammons, David, N., *Municipal Benchmarks: Assessing Local Performance and Establishing Community Standards.* Thousands Oak, CA: Sage Publications, 1996.

Brown, Mark Graham. *Keeping Score: Using the Right Metrics to Drive World Class Performance.* New York: Quality Resources, 1996.

Business Case Analysis for the Long Term Sustainment of the C-17 Globemaster III: Final Report. Prepared for the 516th AESG/CC, Wright-Patterson Air Force Base, Ohio. 2009.

C-5A/B Galaxy. "Air Force Aircraft Factsheets: C-5A/B/C Galaxy & C-5M Super Galaxy." August 16, 2012. http://www.af.mil/information/factsheets/factsheet.asp?fsID=84

C-17A GLOBEMASTER III. "Air Force Aircraft Factsheets: C-17A Globemaster III." December 29, 2011. http://www.af.mil/information/factsheets/factsheet.asp?id=86.

C-130 Hercules. "Air Force Aircraft Factsheets: C-130 Hercules." December 29, 2011. http://www.af.mil/information/factsheets/factsheet.asp?fsID=92

Defense, Space & Security. C-17 Globemaster III Integrated Sustainment Program: Customer. June, 2012. The Boeing Company. http://www.boeing.com/boeing/defense-space/support/integrated_logistics/af/c17gsp.page

E-8C Joint STARS. “Air Force Aircraft Factsheets: E-8C Joint Stars.” May 8, 2012. http://www.af.mil/information/factsheets/factsheet.asp?fsID=100

Examination of the U.S. Air Force's Aircraft Sustainment Needs in the Future and Its Strategy to Meet Those Needs: Assessment of Current Sustainment Investments, Infrastructure, and Processes. http://www.nap.edu/openbook.php?record_id=13177. 2011. P 65-83. The National Academies Press\

Hofbauer, Joachim, Sanders, Greg. Defense Industrial Initiatives Current Issues: Cost Plus Contracts. Center for Strategic & International Issues. Washington, D.C. 2008.

Inspector General United States Department of Defense. Public-Private Partnerships at Air Force Maintenance Depots. June 10, 2010. Report No. D-2010-067.

Kaplan, Robert S., Norton, David P., *Putting the Balances Scorecard to Work.* Harvard Business Review. September-October, 1993, pp. 134-149.

Kem, Dale A, Stouffer, Virginia, Dukocih, John. *Performance Metrics for Assessing Resource Utilization in Business Areas A Focus on Depot Maintenance.* Logistics Management Institute McLean, VA. May, 1999.

Kirkwood, Craig W. *Strategic Decision Making: Multiobjective Decision Analysis with Spreadsheets.* Wadsworth Publishing Company. 1997.

KC-10 Contractor Logistics Support. Northrop Grumman. 2012. http://www.northropgrumman.com/Capabilities/KC10/Documents/kcten.pdf. 2012.

KC-135 Stratotanker. “Air Force Aircraft Factsheets: KC-135 Stratotanker.” December 29, 2011. http://www.af.mil/information/factsheets/factsheet.asp?fsID=110

Logistics, Installations, and Mission Support – Enterprise View (LIMS-EV). Weapons Systems View (WSV) Database. June 1, 1013. https://www.my.af.mil/ledria/ledria/Main.html#

Northrop Grumman E-8C Joint STARS Depot Maintenance. Northrop Grumman 2013. http://www.northropgrumman.com/Capabilities/E8CJointSTARSDepotMaintenance/Pages/default.aspx

Scully, Megan. *High Velocity Maintenance*. Air Force Magazine. August, 2009. pp 44-46.

Warner Robins Air Logistics Center: C-5 Requirements. WR-ALC/GRS briefing by C-5 Fleet Manager. 2011. http://www.wrcoc-aic.org/Archive/RS/RS11/RS11_56.pdf.

Wilhelm, Bruce, Behrens, Steve, Cameron, Ian. *Preliminary Industrial Assessment: An Approach for Developing Depot Sustainment Solutions.* Defense AT&L. November – December, 2011. Vol 6, no. 6. pp 14-18

330th Aircraft Sustainment Group. C-130 Mission Briefing: Requirements Symposium 2008. Briefed by the commanders, 560th Aircraft Sustainment Squadron, Robins Air Force Base, Georgia. http://www.wrcoc-aic.org/archive/rs/rs08/rs08-26.pdf

REPORT DOCUMENTATION PAGE						*Form Approved* *OMB No. 074-0188*
The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of the collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to an penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. **PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.**						
1. REPORT DATE *(DD-MM-YYYY)* 13-06-2013			**2. REPORT TYPE** Master's Graduate Research Project			**3. DATES COVERED** *(From – To)* June 2012 – June 2013
TITLE AND SUBTITLE C-17A Sustainment Performance Metrics Assessment: Repair Source Impact on Sustainment For Future Business Case Analysis Development						**5a. CONTRACT NUMBER**
						5b. GRANT NUMBER
						5c. PROGRAM ELEMENT NUMBER
6. AUTHOR Hall, Zachary G., Major, USAF						**5d. PROJECT NUMBER**
						5e. TASK NUMBER
						5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAMES(S) AND ADDRESS(S) Air Force Institute of Technology Graduate School of Engineering and Management (AFIT/EN) 2950 Hobson Way, Building 642 WPAFB OH 45433-7765						**8. PERFORMING ORGANIZATION REPORT NUMBER** AFIT-ENS-GRP-13-J-17
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Air Force Materiel Command, Lifecycle Management Center 2590 Loop Rd. West, Wright-Patterson AFB, OH 45433-7192 DSN: 785-1505 andrew.ingram@us.af.mil ATTN: Andrew D. Ingram, Colonel, USAF						**10. SPONSOR/MONITOR'S ACRONYM(S)** AFMC/AFLCMC/ASC/WLM
						11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **DISTRUBTION STATEMENT A.** APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.						
13. SUPPLEMENTARY NOTES This material is declared a work of the U.S. Government and is not subject to copyright protection in the United States.						
14. ABSTRACT The C-17A Globemaster III began service on June 14, 1993 and demonstrates some of the highest levels of aircraft availability in the USAF inventory. The sustainment activities responsible for these levels are conducted through a public-private partnership. The Air Force entered this sustainment partnership without the advantage a business case analysis (BCA). In June, 2006, the Department of Defense Inspector General (DoDIG) directed the creation of a BCA for the C-17A program to assess all alternative sustainment strategies, along with recommendations for best-value alternatives. Starting in 2007 and completed in 2009, the BCA provided analysis of three areas for predicting sustainment objective accomplishment: benefits, cost, and risk. While the 2009 BCA encompassed the most detailed assessment of alternatives to-date, it contained shortfalls. Analysis of the benefit metrics showed significant interaction between the chosen metrics resulting in skewed analysis and difficulty discerning between options. The objective of this study was to develop mutually exclusive BCA benefit metrics to assess sustainment strategies, weights to use within a decision analysis framework to better inform future BCAs, and develop business rules to exclude data during transitional phases of sustainment in supporting datasets.						
15. SUBJECT TERMS C-17A Globemaster III, business case analysis, sustainment, aircraft lifecycle, depot performance metrics, non-mission capable supply, maintenance, both, depot time, aircraft availability						
16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON** Dr. Darryl K. Ahner, PhD, PE, AFIT/ENS	
a. REPORT U	**b. ABSTRACT** U	**c. THIS PAGE** U	UU	75	**19b. TELEPHONE NUMBER** *(Include area code)* (937) 255-6565, ext 4708 Darryl.Ahner@afit.edu	